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ATMOSPHERIC AND OCEANOGRAPHIC INFORMATION PROCESSING SYSTEM (AOIPS) SYSTEM DESCRIPTION

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MARCH 1977

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AOIPS SYSTEM DESCRIPTION

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1. INTRODUCTION

The Atmospheric and Oceanographic Information Processing System (AOIPS) is an interactive, minicomputer-based processing and display system that is used primarily for image data analysis and information extraction operations within the Applications Directorate at Goddard Space Flight Center (GSFC). The major hardware components of AOIPS are shown in Figure 1.

Prior to AOIPS, computer-aided data analysis support for applications investigations was conducted on large-scale IBM System/360 computers in a batch-oriented environment without the aid of image display units and with limited capabilities for interaction with image data during the information extraction process. As a result, even simple image processing operations took from days to weeks to produce desired results and required numerous manual, errorprone steps to produce the desired end product. In addition, operations which required a high degree of human interaction with the image data during the information extraction process (e.g., derivation of wind fields from cloud motions in a time-lapsed series of satellite images) were not practical in the batch environment.

Computer-aided data analysis support was needed to help applications investigators perform the interactive image data analysis processes rapidly and to eliminate the inefficiencies and problems encountered with the batch operation discussed above.

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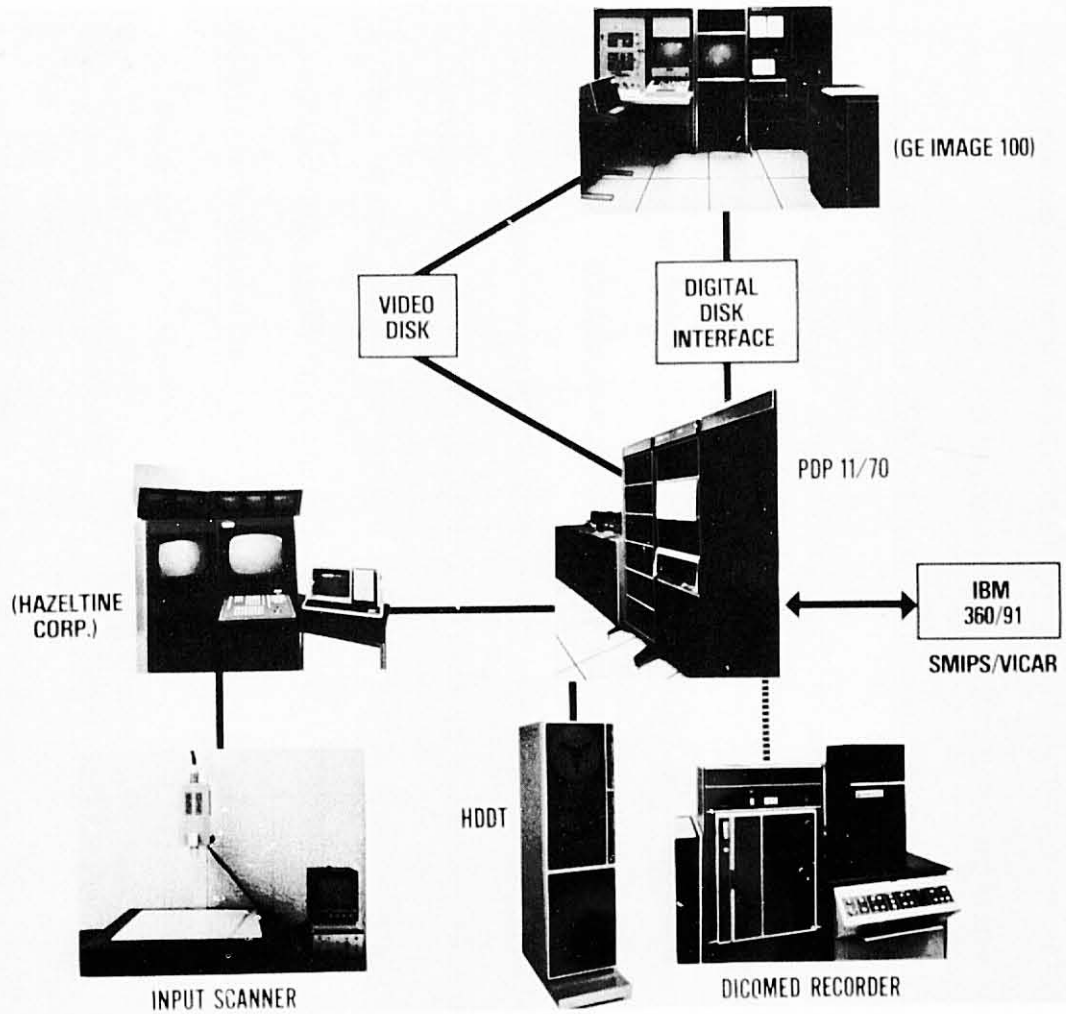

Figure 1. Atmospheric and Oceanographic Information Processing System - AOIPS

In early 1975, a requirements analysis was conducted to determine the information extraction needs of weather and climate, oceanography, and Earth resources investigations at Goddard Space Flight Center. As a result of this analysis, a preliminary systems concept evolved, which resulted in the design and specification of the AOIPS system. Procurement activities for the various system components were conducted during 1975 and 1976. The initial hardware deliveries consisted of a PDP-11/70 computer and peripherals and a modified General Electric Company Image 100 system, which included both an interactive terminal and a PDP-11/45 computer. The Image 100 system was designated as AOIPS Image Analysis Terminal 1 (IAT 1). A second image analysis terminal, designed at Goddard Space Flight Center and implemented by Hazeltine Corporation, was delivered in May 1976. This terminal has been designated as AOIPS Image Analysis Terminal 2 (IAT 2).

In parallel with the hardware development activities, a series of applications software packages was developed to implement specific information extraction processes in response to the requirements established in 1975.

Since it began operations in December 1975, AOIPS has demonstrated its capability to solve many operational data processing problems, and has greatly extended the investigator's ability to perform image information extraction operations in a flexible, efficient manner, which is conducive to the development of new data analysis procedures and to creative applications research.

Image Analysis Terminal 1 has been scheduled for two shifts a day, seven days a week since December 1975 for data analysis operations and software development. Terminal 2 has been operational for meteorological investigations support since November 1976 and has experienced similar use. Currently, both AOIPS terminals are used two shifts a day, six to seven days a week in support of over 20 major applications investigations.

Further system enhancements are planned during 1977, with the expectation that major software development activities will continue for several more years in support of ongoing applications research.

The remainder of this document contains five additional sections. An overview of the system is given in Section 2, a description of system hardware in Section 3, an overview of the system software in Section 4, a brief statement on the major applications supported in Section 5, and a description of the hardware and software enhancements planned for the future in Section 6.

2. AOIPS SYSTEM OVERVIEW

The heart of the AOIPS is a Digital Equipment Corporation PDP-11/70 computer to which three magnetic tape drives, two disk units and other standard peripherals are attached. Two image analysis terminals interfaced to the PDP-11/70 central processing unit provide for user interaction in the extraction of information from digital images.

Terminal 1 (see Figure 2) is a General Electric Company Image 100 system modified to provide capabilities for time lapsed display of image data and for output of video signals to a video disk storage unit. Control of this terminal is provided by its own PDP-11/45 computer. Digital images on computer-compatible tapes are loaded into a 5-channel solid-state refresh memory from two 800/1600-bit-per-inch (bpi), 9-track tape drives. The contents of the refresh memory channels are input to analysis console digital logic for ratioing, scaling, and limit comparison; the output of these operations is displayed on both color and black and white TV monitors. Using the analysis console logic, image enhancement and multispectral classification analyses are performed under control of software on the PDP-11/45. Terminal 1 is interfaced to the AOIPS PDP-11/70 computer through a dual-port, shared-disk unit capable of formatted storage of 88 megabytes (8 bits per byte) of data.

Terminal 2 (see Figure 3) is a versatile image analysis console built to Goddard Space Flight Center specifications by the Hazeltine Corporation. It

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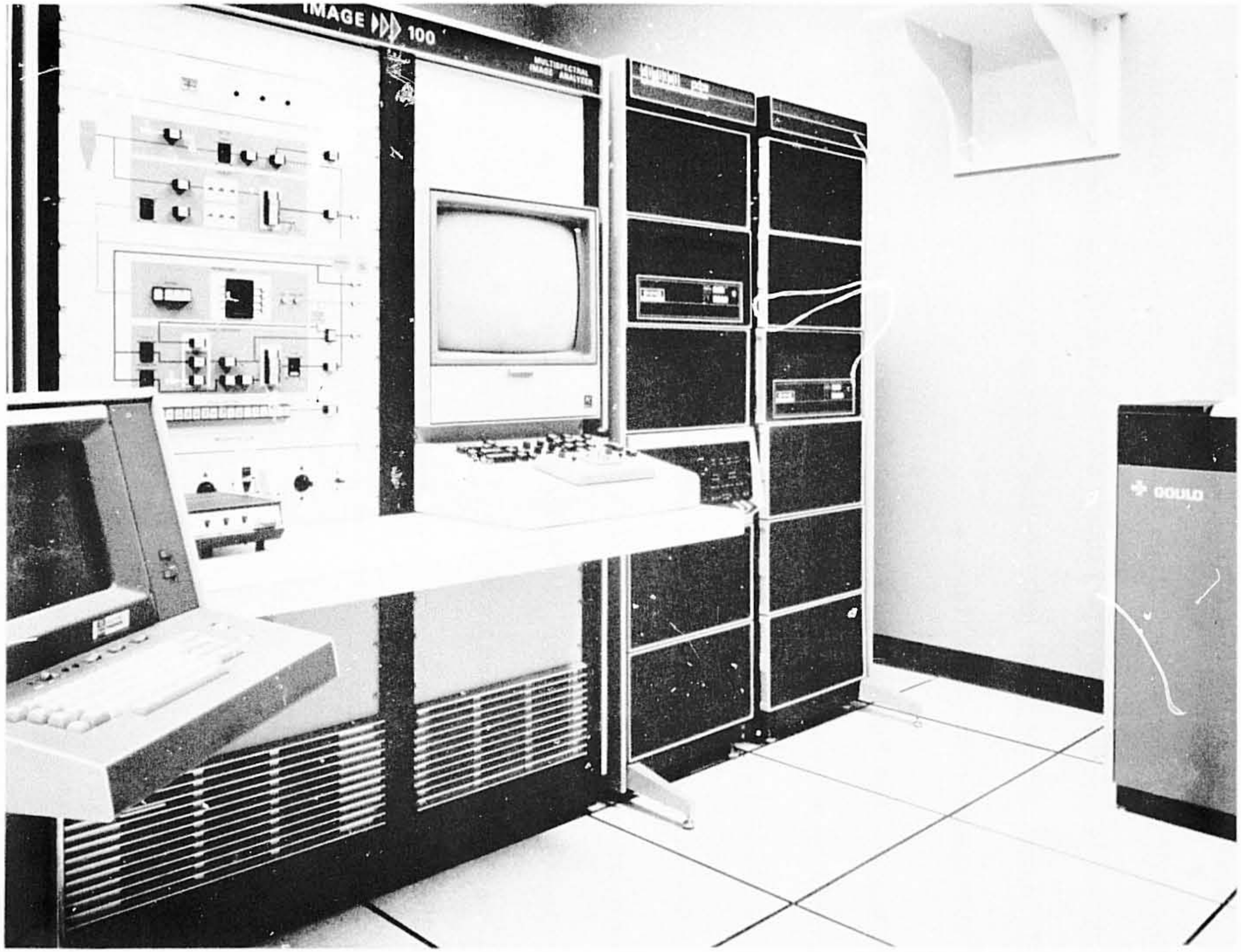

Figure 2. Image Analysis Terminal 1 - Image 100 System

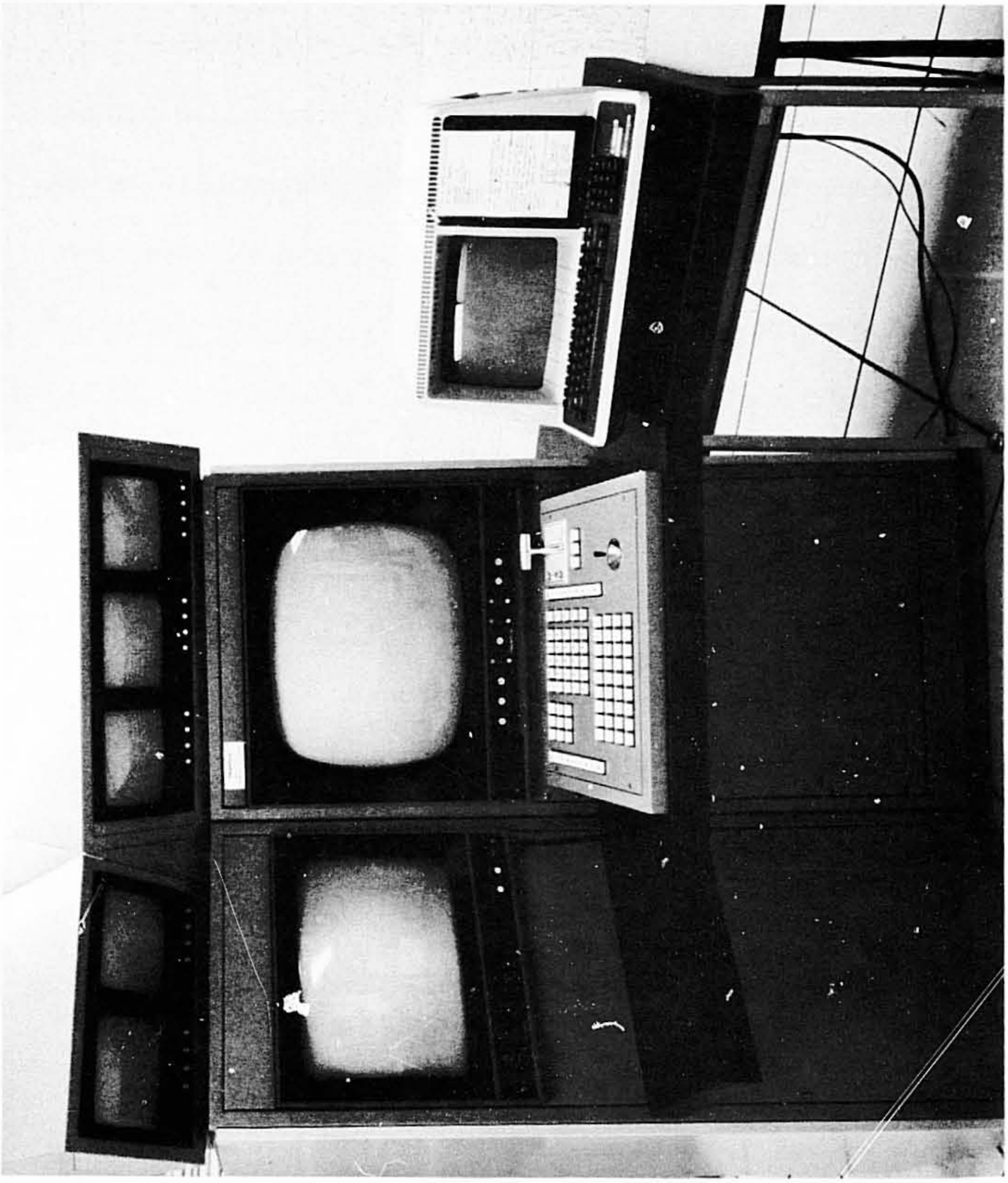

Figure 3. Image Analysis Terminal 2

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is interfaced directly to the PDP-11/70 through a high-speed direct memory access interface for control signals. Using the three 800/1600 bpi, 9-track tape drives of the PDP-11/70, digital images on computer-compatible tapes are loaded into the 5-channel solid-state refresh memory of Terminal 2. Images may also be loaded from disk or from maps or photographs digitized by a video input scanner interfaced to the terminal. The contents of the refresh memory channels pass through lookup tables, digital matrix switches, and other image manipulation logic in the console. Image enhancement and parameter extraction analyses are performed under control of software on the PDP-11/70.

The video disk, which is connected to both terminals through a video switching system, has the capacity to store up to 600 TV-sized images. Using the switching system, images may be recorded from or played back to the TV monitors of either terminal.

A High Density Digital Tape unit (see Figure 1) is also interconnected to the PDP-11/70 computer. This unit utilizes a 14-track instrumentation tape recorder to record and/or playback digital data on 10 data tracks at a packing density of 20,250 bpi per track.

The AOIPS PDP-11/70 computer communicates with a remotely located IBM S/360/91 computer through a 4800-bit-per-second telephone line connection.

A Dicomed Image Recorder (shown in Figure 1) functions as an off-line device to convert information recorded on computer-compatible tapes (CCTs) into photo products of image and related ancillary data.

A more detailed description of the system hardware components is presented in Section 3 and Appendices 2 and 3.

AOIPS utilizes computer-compatible tapes of multispectral digital image data generated by satellite and aircraft image scanners as well as related digital ancillary data required to perform specific information extraction operations. In the future, high density digital tapes will provide the primary input medium for meteorological satellite data. The system provides capabilities for inputting digital data in several formats; performing standard image preprocessing operations including image registration, geometric correction, scanner distortion correction, and zooming and reducing subimages; executing image processing functions including level slicing, contrast enhancement, pseudo color and false color combinations, band ratioing, linear combinations, and histogram generation; performing analytical operations including multispectral classification and special applications analyses; and displaying and generating hardcopy output of single images and of images overlayed with data plots, contours and various forms of image annotation.

2.1 User Interface to AOIPS

There are two types of users supported on the AOIPS: (1) applications investigators who specify and perform information extraction operations on the system for specific applications and (2) programmer/analysts who develop new systems and applications software. Applications investigators interface with the system by requesting execution of various system processes from menus presented on interactive cathode ray tube display units. Adopting the menu approach as the primary user interface has simplified training problems and virtually eliminated the requirement for a user to learn a new computer language. A discipline oriented user is led through the entire sequence of possible processing options available by a series of prompts and a layered structure of menus which require simple responses.

As an example of this approach, Figure 4 shows the Main Menu for the AOIPS Support Package (ASP). ASP was developed to provide investigators with capabilities to process and manipulate image data. A description of ASP capabilities is included in Section 4.2.7. A user interacts with ASP by first selecting the processing function he requires from the ASP Main Menu and typing in a number to indicate his choice. For example, if the user wishes to perform a contrast stretch on an image, he would type a "6" followed by a carriage return on the display unit keyboard. The ASP system would immediately respond by displaying the Contrast Stretch Menu presented in Figure 5.

```
ASP                              MAIN MENU

                            (FUNCTION SELECTION)

SELECT ONE OF THE FOLLOWING ASP FUNCTIONS BY KEYING IN

THE NUMBER CORRESPONDING TO THE FUNCTION IDENTIFIER

0        RETURN TO CONTROL MENU

1        ENTER IMAGES INTO ASP                        11

2        GENERAL DISPLAY                              12

3        ASP OUTPUT PRODUCTS                          13

4        IMAGE PIXEL LIST                             14

5        HISTOGRAM                                    15

6        CONTRAST STRETCH                             16

7        PSEUDO COLOR                                 17

8        IMAGE FUNCTION                               18

9                                                     19

10                                                    20
```

Explanation: This main menu allows the user to select one of the ASP functions for processing.

Example:

User Response:

6 (carriage return)

System Response: The Contrast Stretch Function is invoked prompting the user with the menu in Figure 5 for selection of one of the available stretch options.

Figure 4. AOIPS Support System - Main Menu

```
SPECIFY STRETCH FUNCTION TO BE APPLIED

     -1-   LINEAR STRETCH

     -2-   TABLE STRETCH

     -3-   BIT CLIPPING STRETCH

     -4-   POWER STRETCH
```

Figure 5. AOIPS Support System - Contrast Stretch Menu

A sequence of menus, prompts, and user responses continues until the ASP software has enough input to execute and display the results of the contrast stretch operation as dictated by the user responses.

Typical user data analysis sessions last for about two hours. During a session, the user has several options available to him for displaying intermediate results, generating output products, and defining sequences of processing operations. Operations may be terminated with the capability to restart in subsequent analysis sessions on the system. The user has the option to start and to save/restart analysis sessions using magnetic tape and/or disk units. The disk operations provide a significant speed advantage over the magnetic tape operations.

The second type of system user, the programmer/analyst, typically utilizes operating system facilities and the operating system commands to code, compile, link, edit, and checkout the software being developed. The

programmer/analyst does not usually interact in the menu environment until the final checkout and integration phase in the development of a new applications software package.

2.2 System Constraints

Several design constraints inherent in the AOIPS limit its flexibility for certain image processing applications. The first constraint is dictated by the size of the solid-state refresh memories on each of the AOIPS Image Analysis Terminals. Each refresh memory consists of five refresh channels of 512 lines by 512 picture elements per line with an 8-bit representation for each picture element. (Normally, each TV picture element represents one instantaneous field of view of the scanner used to sample a ground scene.) Typically, aircraft and satellite scanner images contain many thousands of picture elements per ground scene and aircraft scanners can generate images in up to 24 spectral channels.

The size limitation of the AOIPS refresh memories restricts the user to displays (and other processing operations which use the refresh memories) of five or fewer spectral bands at a time in subimages of 512 or fewer scan lines by 512 or fewer picture elements per scan line.

For Landsat MSS data users, this corresponds to processing one-thirtieth of a full Landsat scene per operation. Because most investigators are interested in extracting information about features in small subareas of

scanner images rather than over the entire scene, this restriction has not severely impacted data analysis operations.

The restriction of operating on 5 or fewer spectral channels of a multispectral image in processing operations has not proved to be a severe limitation due to the system's ability to reload the refresh memories in seconds from the system disk units. Addition of a planned third image analysis terminal will provide capabilities for operating on up to 10 images on the PDP-11/70 system.

The restriction of operating on image data represented by eight or fewer bits requires that certain processing operations for existing 10-bit aircraft scanner data be performed entirely with software in the host computer's core memory. The results of such operations are recorded to the desired accuracy but are displayed using only the eight most significant bits.

One additional restriction is that input data must reside on a computer-compatible tape in a format acceptable to the system (Section 2.3 includes acceptable input tape formats), or must be in a form acceptable for entry into the system through the TV input scanner unit, or must have been stored on a system disk unit as the result of a previous AOIPS user session.

2.3 System Inputs

The AOIPS is capable of reading data from computer compatible tapes (CCTs) in any of the following formats:

- Landsat CCT format

  Full Landsat 185 km x 185 km frames are generated in 4 vertical strips. These strips may be stored on separate CCTs or in separate files of one CCT in the format described in Reference 1.

- SMS VISSR images

  Images in either the NOAA Ingest Data Tape Format (Reference 2) or in the GSFC AOIPS picture tape format (Reference 3) are acceptable as input.

- VICAR format tapes produced by SMIPS/VICAR

  The Small Interactive Image Processing System (SMIPS) is Goddard Space Flight Center's version of the Jet Propulsion Laboratory's Video Image Communication and Retrieval (VICAR) image processing system. SMIPS executes on an IBM 360/91 computer. Details of the VICAR tape format may be found in Reference 4.

- Universal Tape Format

  This format is used by NASA Johnson Space Center and the Canada Centre for Remote Sensing. The header record, described in Reference 5, defines the structure of data records on the tape.

- Aircraft scanner tapes

  Tapes conforming to the format described in Reference 6 containing data from the Heat Capacity Mapper, the Ocean Color Scanner, and

other aircraft scanners are acceptable as input.

- LARSYS II or III format Multispectral Image Storage Tapes (Reference 7) from the Laboratory for Applications of Remote Sensing of Purdue University.

- Image data tapes having AOIPS-compatible label records (the AOIPS tape label format is described in Appendix 1).

In addition, the AOIPS TV input scanner unit provides capabilities for digitizing maps, charts, transparencies, photographs, and other similar information for input to the system.

Data may also be entered into the system from punched cards or from disk storage as a result of a save operation from a previous AOIPS user session. In the future, high density digital tapes will also be utilized as an input medium.

2.4 Image Processing Options

Once a user's data has been entered into the system, a variety of image processing operations are available through several subsystems and application software packages.

- Image Registration - Pairs of images may be registered by translating one with respect to another. The amount of translation required is determined by the identification of landmarks.

- Aspect Ratio Correction - Corrections may be applied for scanner distortions such as foreshortening and nonsquare picture elements. Landsat images may be corrected for Earth rotation.

- Image Enhancement - The functions available to the user include:
  - Contrast stretching (several options are available)
  - Band ratioing
  - Linear combination of images
  - Pseudocolor and false color displays

- Quantitative Analysis - Histograms of frequency versus grey level may be compiled and displayed for selected subimages. Statistics (mean, standard deviation, etc.) are also computed and displayed for the selected areas. Contours of derived parameters may be generated and overlayed on the user's image.

The specific processing options available within AOIPS are more fully described in Sections 3 and 4.

2.5 Display Options

A user can display image data in various black and white and color presentations. He can select options to zoom in on subimages, to reduce large images to TV size sequences of images, to present split-screen displays, and to utilize various shaped cursors to outline and define image features of interest. The user can also utilize the table lookup capabilities of Terminal 2 to display

various color and black and white enhancements of image data. He can also display grids, maps, data plots, contours, and feature boundaries superimposed on image data.

2.6 Analysis Operations

For Earth resources users, the primary data analysis capability provided in AOIPS is multispectral classification. Options are provided for supervised classification using either a parallelepiped or a maximum likelihood algorithm. The AOIPS maximum-likelihood classifier provides a highly flexible, interactive menu driven package for selecting, defining, combining and editing training sites and training site statistics.

For meteorological users, the primary data analysis capabilities provided in AOIPS include cloud tracking/wind field generation utilizing a time lapsed series of images and capabilities to perform various computations on and analyses of the generated wind fields. Capabilities also exist for analyzing the dynamics of cloud development, for determining cloud heights and for generating color contours of cloud temperature profiles.

A more detailed discussion of AOIPS data analysis capabilities is contained in Sections 4 and 5.

2.7 Output Products

The user can select shade prints of image areas, Dicomed photo output products of images or images overlaid with contours and data plots, computer

printouts, and computer-compatible tapes or disk data sets of intermediate and final analysis results.

Samples of AOIPS output products are presented in Section 5.

2.8 Data Management Capabilities

The AOIPS system software is designed to provide automatic cataloging and tracking of data sets once the data has been entered into the system. At appropriate places in the information extraction process, the user selects the desired data sets to be processed from data selection menus. These menus typically display catalogs of data sets currently resident on system storage devices and allow the user to input additional data sets and name new data sets for future reference where appropriate.

Data management capabilities also exist to allow users to pass disk and tape data sets between the major AOIPS applications packages described in Section 4. This arrangement allows users to access processing capabilities of several individual software packages even though these packages may have been written for dissimilar applications. For example, a user analyzing Heat Capacity Mapper (HCM) aircraft data can transfer HCM data sets from his application software package to a meteorological package in order to exercise certain image registration capabilities available in the meteorological package.

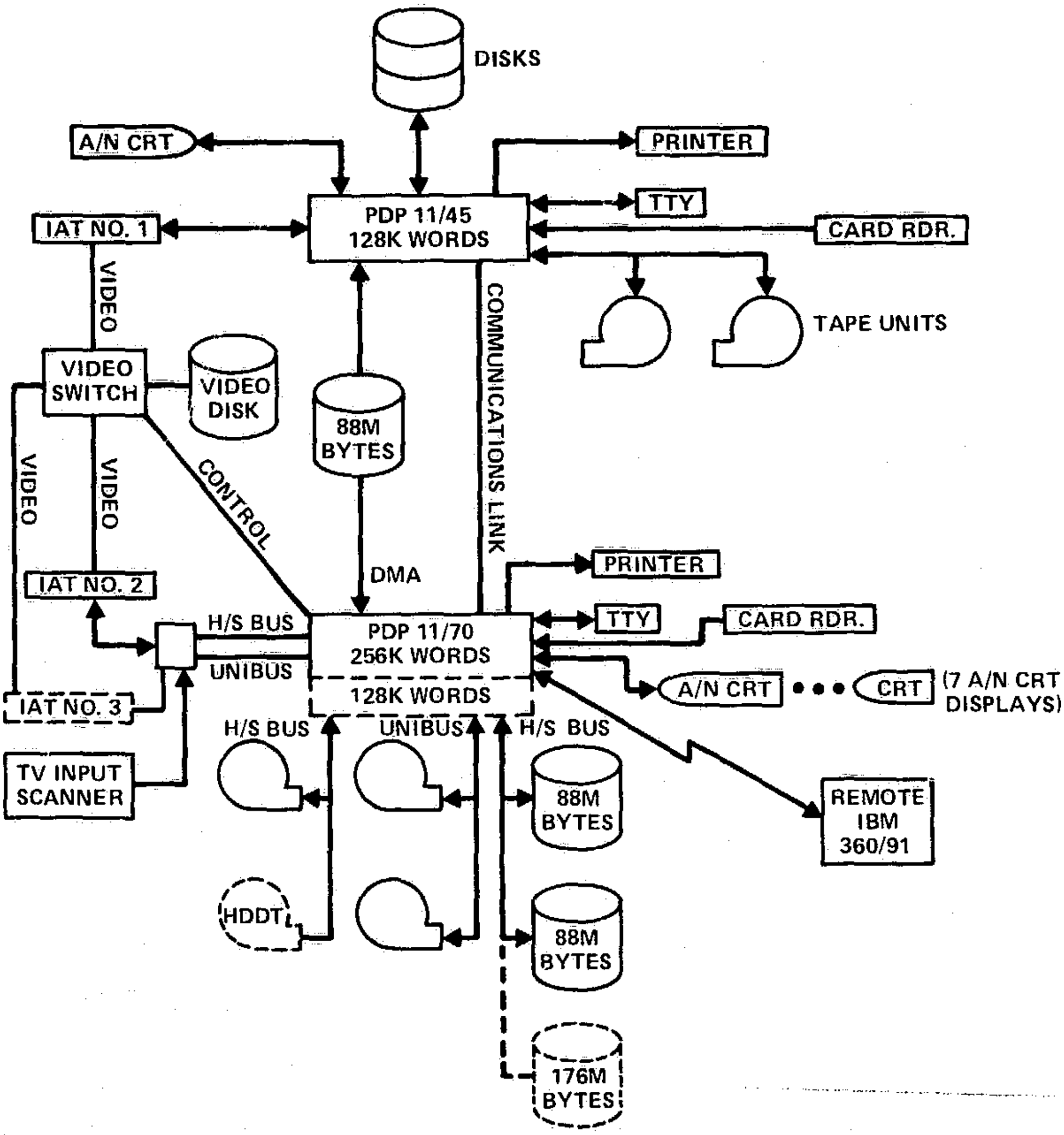
Additional data management capabilities are described in Section 4.

3. AOIPS HARDWARE DESCRIPTION

A more detailed version of the AOIPS hardware block diagram is presented in Figure 6. The items outlined with solid lines indicate existing equipment and those outlined with dashed lines indicate hardware acquisitions planned during 1977. The planned acquisitions include a third Image Analysis Terminal (identical with IAT 2), the High Density Digital Tape Drive mentioned earlier and a dual-density (176 megabyte) disk unit.

Figure 6 indicates which devices are interfaced to the PDP-11/70 through high-speed direct memory access (DMA) channels and which devices are interfaced through the UNIBUS input/output channel. The interface between IAT 2, IAT 3, and the PDP-11/70 is a dual interface in which all high-volume data transfers use a high-speed channel and all low data volume, control signal information transfers use a UNIBUS channel interface.

Figure 6 indicates the functional interconnections of the video switching system incorporated into the AOIPS configuration. All video signals from the three Image Analysis Terminals are routed to the video switching unit. The video switch itself is under computer control from the PDP-11/70. By utilizing this control link, any video signal within the system can be routed to the video disk for storage, to video recorders, and to a large Advent TV projection screen or other TV monitors interfaced to the switching unit. It is also possible to display video which originates in any one of the terminals on any



DOTTED ITEMS INDICATE HARDWARE ACQUISITIONS PLANNED FOR 1977.

Figure 6. AOIPS System Hardware Configuration

other terminal. This capability will be utilized for applications requiring simultaneous use of multiple image analysis terminals during information extraction operations. In addition, the video disk unit can be used to store sequences of up to 600 TV sized (512 by 512) images for time-lapsed playback through the system.

Figure 6 also indicates the 9600-bit-per-second back-to-back DL11 teletype interface link between the PDP-11/45 and -11/70 computers. This link is used primarily to communicate synchronization and control information between the two central processing units during shared disk operations.

The shared disk unit is used to transfer data between the image analysis terminals, to transfer results of a TV input scanner operation to Terminal 1, and to provide a medium for sharing peripheral equipment between the PDP-11/70 and 11/45 computers.

The TV input scanner scans image data into any user selected channel of one of the refresh memories of either Terminal 2 or 3. The contents of this refresh channel can be rerouted to any storage device or any image display unit in the system.

After Terminal 3 is installed (April 1977), one of the 88-megabyte disk units shown in Figure 6 will be dedicated to Terminal 2 users for save/restart operations, the second 88-megabyte disk will be dedicated to Terminal 3 users, and the 176-megabyte disk will be used to support system functions and software

development activities. In addition, users on either of the PDP-11/70 Image Analysis Terminals will be able to select from one to ten refresh memory channels for their image processing operations.

The PDP-11/70-S/360/91 computer link shown in Figure 6 consists of a 4800-bit-per-second remote job entry communications link. This communications path will be upgraded to a 50-kilobit-per-second link in late 1977. It will provide capabilities for AOIPS users to perform large computational jobs on the high-speed IBM S/360/91 computer and to display and analyze the results of these computations on AOIPS. The kinds of information extraction tasks requiring this support include multispectral classification of large subimages or full images and various kinds of weather, climate, and Earth resources modeling activities.

Experience in interfacing various kinds of equipment to the AOIPS PDP-11/70 computer indicates that from 50% to 70% of the total theoretical system input/output bandwidth (5.8 megabytes per second) can be achieved in the current configuration. Figure 7 is an estimate of the system input/output bandwidth achievable for various levels of system activity within the current AOIPS configuration.

Experience with the AOIPS 88-megabyte disk units indicates that 60% to 70% of the theoretical input/output bandwidth (675,840 bytes per second) can be achieved in the current system configuration. Table 1 lists the results of

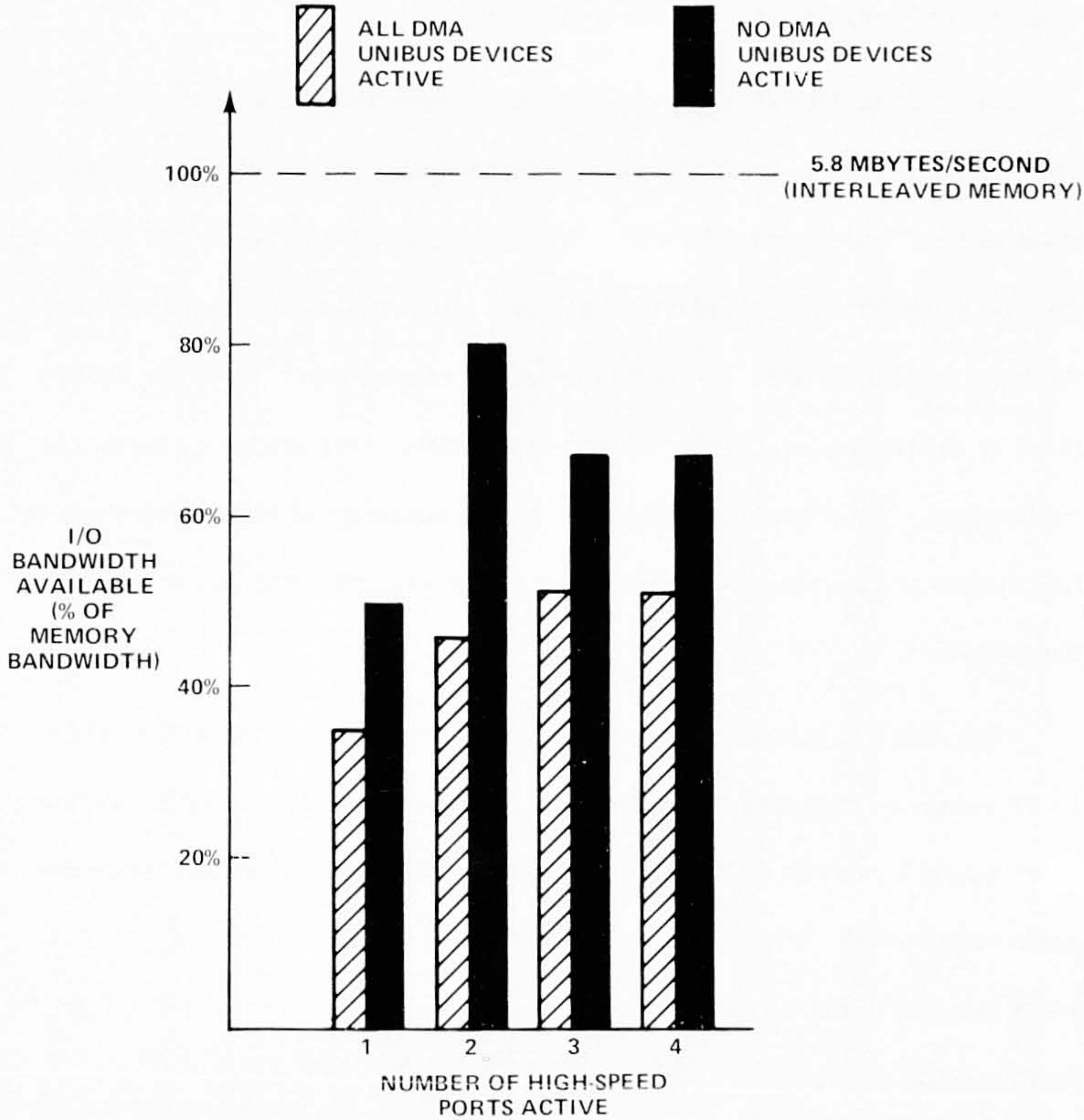


Figure 7. AOIPS I/O Bandwidth vs. System Activity

benchmark tests performed on the 88-megabyte disks in the current AOIPS configuration.

Table 1. Fortran I/O vs FSTVID* for 262, 144 Byte Transfer to RP04

Time in seconds (effective transfer rate in K bytes/second) vs Block size

Record Size (bytes)	Number of Records	11/45 FORTRAN	11/70 FORTRAN	11/45 & 11/70 FSTVID
512	512	17.5 (15.0)	8.9 (29.5)	8.9 (29.5)
1024	256	21.7 (12.1)	13.1 (20.0)	4.7 (55.8)
2048	128	21.7 (12.1)	13.1 (20.0)	2.5 (104.9)
4096	64	21.7 (12.1)	14.2 (18.5)	1.5 (174.8)
8192	32	21.7 (12.1)	14.2 (18.5)	.95 (275.9)
16384	16	21.7 (12.1)	14.1 (18.6)	.68 (385.5)

*FSTVID is a utility package designed to support efficient disk operations. See Section 4.5.3.

These achievable input/output bandwidths allow the transfer of approximately two TV-sized images per second to and from the Terminal 2 refresh memory. Addition of the High Density Digital Tape unit will allow the transfer of up to five images per second to and from the Terminal 2 and 3 refresh memories.

Addition of Terminal 3 will result in approximately 80% of the achievable system bandwidth being used during planned peak load conditions. For this reason, no additional image analysis terminals will be attached to the existing AOIPS PDP-11/70 computer in the future.

Further information about the alternative hardware configurations and peak load conditions considered for AOIPS is presented in Reference 8.

3.1 PDP-11/45 - Image Analysis Terminal 1

The hardware configuration for the AOIPS PDP-11/45 Terminal 1 subsystem is shown in Figure 8. A detailed list delineating equipment model numbers and describing equipment characteristics is presented in Appendix 2.

Terminal 1 includes a GE Image 100 system (shown in Figure 2). The Image 100 Multispectral Image Analyzer Console contains special-purpose hardware which operates in conjunction with the Image 100 software described in Section 4 to rapidly analyze multispectral image data.

The Image 100 console processing hardware is designed to process image data, particularly Landsat data, and to perform a parallelepiped classification of multispectral data. The user interacts with the Image Analyzer Console to execute processing functions, to select training sites, and to manipulate themes generated as a result of a classification operation.

The Image 100 Image Analyzer Console performs the following functions in hardware:

- Image Correlation - Two images are displayed alternately in a flicker presentation for image comparison and registration operations.

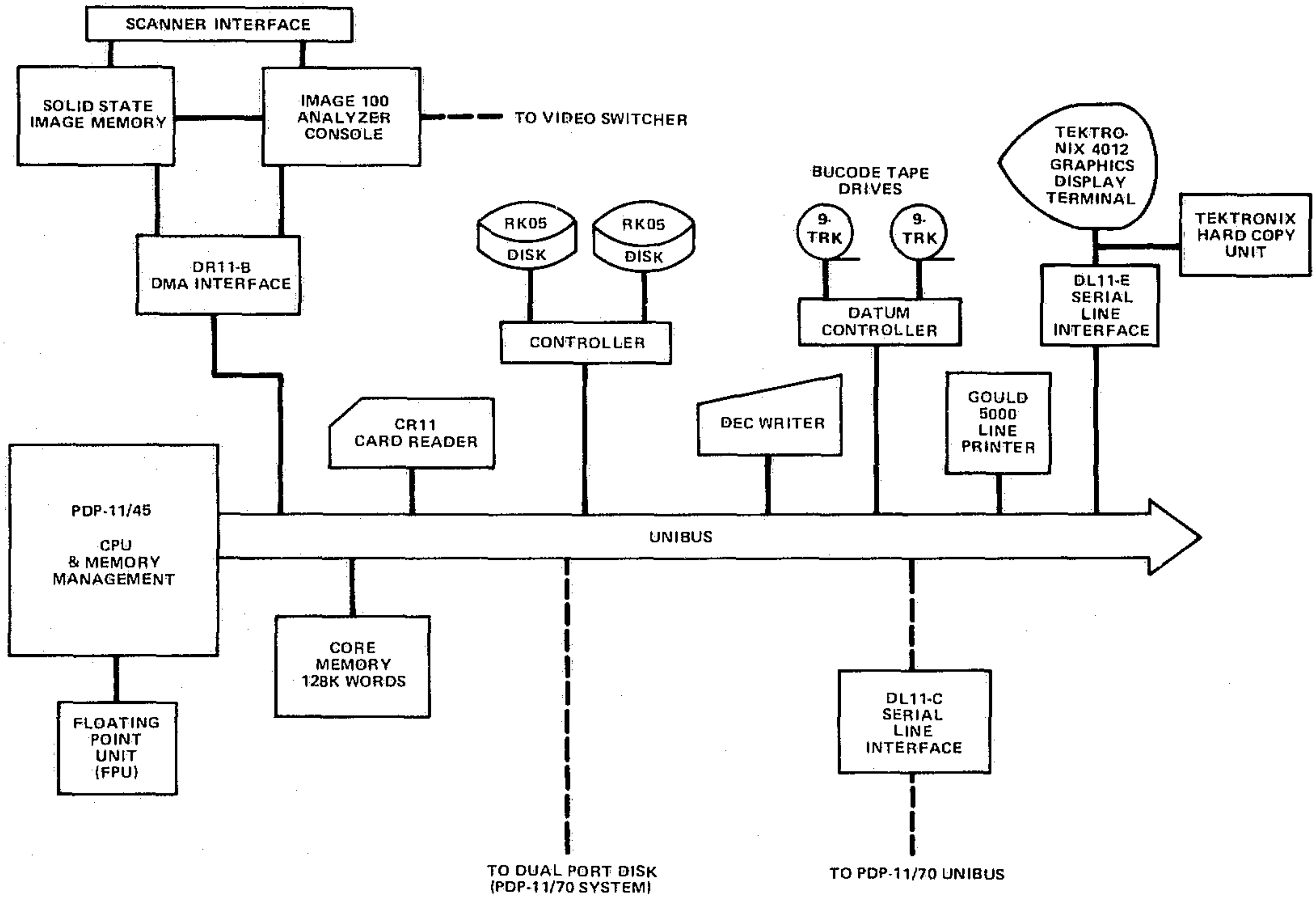


Figure 8. AOIPS PDP-11/45 - Terminal 1 Configuration

- Image Scaling - Thumbwheel switches are used to perform individual amplitude scaling shifts on each refresh memory channel.

- Ratioing - Images stored in the refresh memories may be ratioed and the results of the ratio operation displayed on the TV display unit.

- Image Transformation - General purpose transformation hardware exists to rotate feature axes in spectral space.

- Spectral Signature Acquisition - Hardware exists to compile histograms (frequency versus digital grey level) of areas specified by the user in each refresh memory channel. From these histograms, upper and lower grey level limits are obtained to serve as a four-dimensional parallelepiped describing the spectral signature of the specified area.

- Cursor Control - A multimode hardware cursor is sized and positioned by joystick control for the definition and selection of subimage areas.

- Image Analyzer - Special-purpose digital logic operates under software control to store and test for upper and lower grey level limits in each refresh memory channel. Parallelepiped signature regions are synthesized into decision boundaries by the Image Analyzer for classification operations.

- Theme Synthesizer - Circuitry is included in the Image Analyzer to combine themes using logical AND, OR, Exclusive OR, and theme inversion operations.

- Color TV Display - A color TV display provides capabilities to display image data, the results of various processing functions and thematic results of classification operations. Software also exists to generate split screen presentations.

Terminal 1 also incorporates hardware modifications for transferring video signals to and from the AOIPS video switching unit. Further information about Terminal 1 is contained in Reference 9.

The two RK05 disk units shown in Figure 8 are used primarily for program storage. The dual ported RP04 disk shared with the PDP-11/70 is used for data storage and for transferring data to and from peripherals attached to the PDP-11/70 computer. Currently, the shared disk is used in a half-duplex, 'manual' mode where operator mount/dismount commands are issued to commit the shared disk to either processor. Section 6 describes software under development which automates a half duplex shared disk operation on AOIPS. The back-to-back DL11-C Serial Line Interfaces shown in Figure 8 (and in Figure 9) will be used by the shared disk software to transmit synchronization and control information between the PDP-11/45 and -11/70 processors.

3.2 PDP-11/70 - Image Analysis Terminal 2

The hardware configuration for the AOIPS PDP-11/70 - Terminal 2 subsystem is delineated in Figure 9. Terminal 3 is also shown as it will be interfaced to the PDP-11/70 in late Spring 1977.

A detailed list of equipment model numbers and equipment characteristics is contained in Appendix 3.

Terminal 2 is a state-of-the-art hardware configuration which provides significant image processing capabilities that are not available in second generation terminals currently being marketed. Figure 3 depicts the terminal analyzer console as seen by the terminal user. The terminal was designed to register, process, display, and analyze digital image data for a wide variety of applications. It rapidly performs many image manipulation functions in special purpose hardware which is set up and controlled by the AOIPS PDP-11/70 computer.

Computer control of the terminal hardware allows applications system designers to include hardware control functions in software designs and provides the capability to utilize the full power of the terminal to meet image processing requirements in a highly flexible and responsive system environment.

Figure 10 presents a block diagram of Terminal 2 logic components. Noteworthy elements in Figure 10 include the hardware lookup tables, the

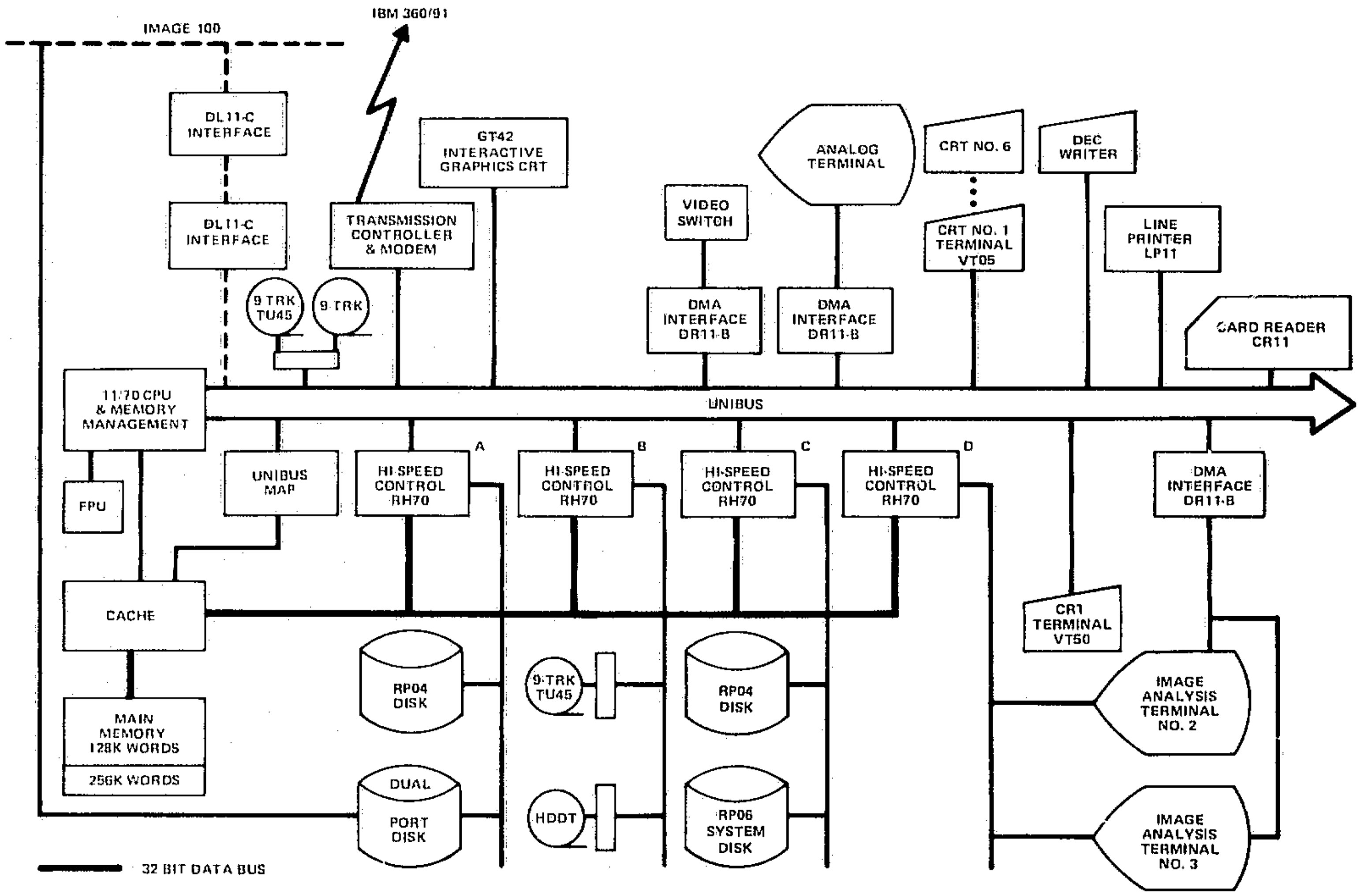


Figure 9. AOIPS PDP-11/70 - Terminal 2 Configuration

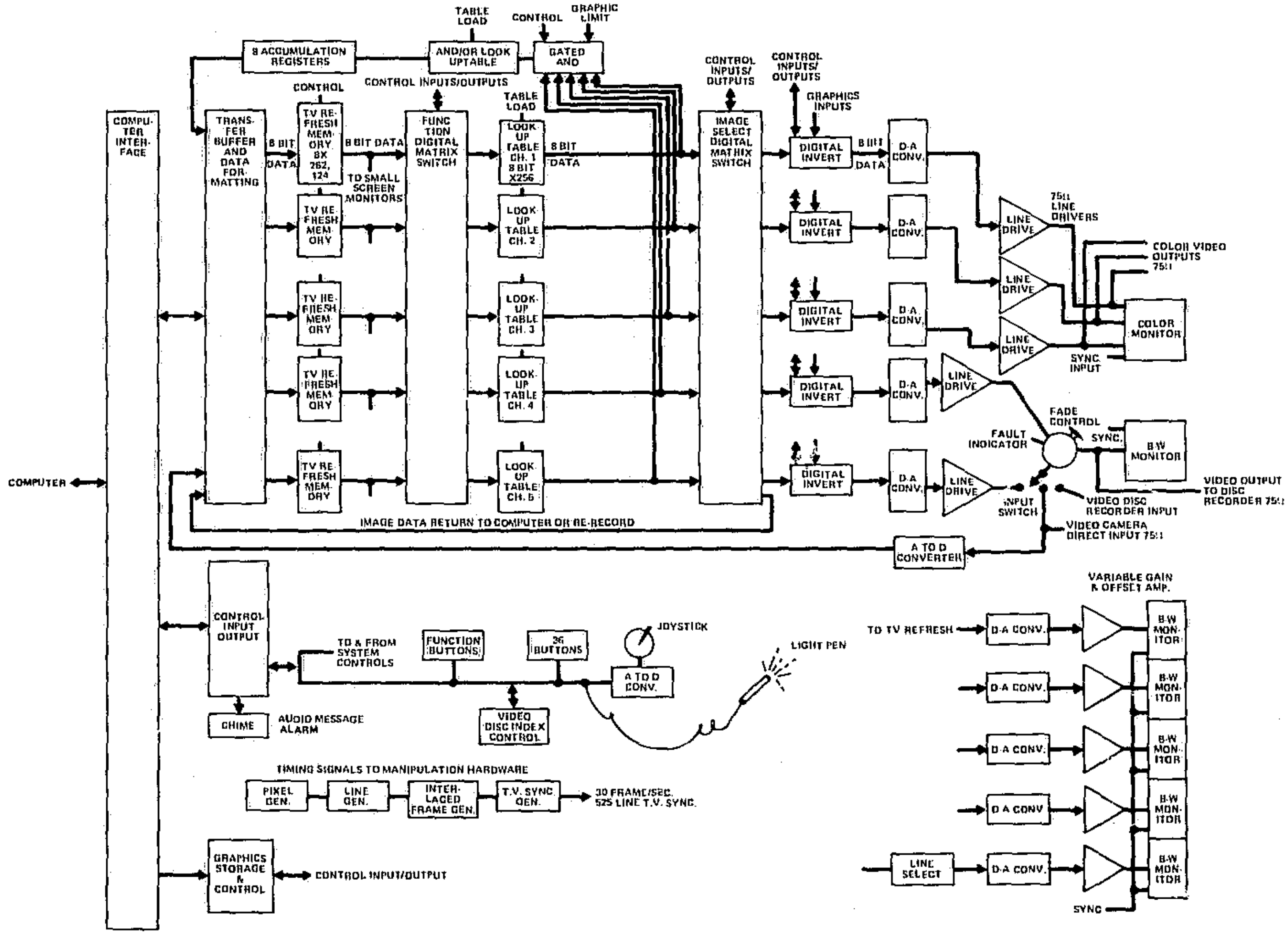


Figure 10. Image Analysis Terminal 2 Logic Diagram

digital matrix switches, a light pen, the programmable function button array, and the five solid state refresh memories. Refresh memory 5 is randomly addressable to the bit, byte (8 bits) or word (16 bits) level. Each of the refresh memories 1 through 4 are randomly addressable in groups of 16 words.

Terminal 2 provides hardware capabilities for:

- Image Display - The contents of each refresh memory channel are displayed on individual black and white TV monitors. Any refresh channel can also be displayed on a high quality, twenty-one inch black and white monitor. False color displays combining any three refresh channels as well as pseudocolor presentations of individual channels are displayed on a nineteen inch color TV monitor.

- Time Lapse Display - Terminal 2 provides time lapsed display of up to five TV sized images in a movie loop presentation. After installation of Terminal 3, capabilities to display time lapsed sequences of up to 10 images will be provided.

- Image Correlation - A hardware fade control is used for simultaneous display of two images during image registration and correlation operations.

- Image Translation - Hardware capability is provided for X-Y translation of images within the refresh memories under joystick control for rapid image registration.

- Graphic Overlay - Graphic overlay of image data sets with a cursor, a rectangle, randomly shaped polygons, plots and data contours is provided.

- Joystick Control - Computer control of a hardware joystick is provided to select the size and position of graphic overlays including a multi-mode hardware cursor, to select single picture elements or entire subimages, to control the direction and speed of image scrolling operations, to fly one image over another for rapid image registration, and to control the speed of dynamic color table lookup 'rolling' operations.

- Image Scrolling - Flight line display of image data sets is provided under joystick control.

- Split Screen Displays - Simultaneous multiple image split screen displays are provided.

- Lookup Tables - Hardware lookup tables are used for dynamic color rolling for continuous changing of grey level - color assignments, radiometric correction, parallelepiped classification (up to 9 spectral channels and 8 classes), level slicing and contrast stretching. Each of these operations is performed within 1/30th of a second.

- Light Pen Detection - A light pen is used to outline and select irregularly shaped image areas for processing.

- Signature Acquisition - A series of hardware registers is used to rapidly generate grey level histograms of image areas for spectral signature acquisition.

- Theme Synthesis - Thematic information is synthesized using the lookup tables and matrix switches.

- Image Combination - Images in individual refresh channels can be combined and re-recorded into the refresh memory.

- Scanner Input - A TV input scanner is utilized to digitize information and store it in any refresh memory channel.

- Video Transfers - All video signals are transferred to or from the AOIPS video switching unit and the video disk unit.

- Direct Data Readout - Manipulated images and picture elements within a boundary may be transferred back to the PDP-11/70 computer for further analysis.

- Processing Control - A CRT keyboard display unit and an array of programmable function buttons are used to control the sequence of processing operations and to create new analysis scenarios.

The terminal hardware performs computer controlled image manipulation functions in real time while the user observes each operation. Image transfers from the computer to the terminal refresh memories occur at a

rate of two images per second from disk units and at five images per second from the AOIPS High Density Digital Tape unit. Terminals 2 and 3 will be fully interconnected to share resources thus allowing a user on either terminal to use up to 10 refresh memories to support data analysis operations.

Terminal 2 is used primarily for meteorological applications in support of severe storms research investigations. Terminal 3 will be dedicated to information extraction technique development in support of severe storm forecasting investigations utilizing data from multiple satellite sensors and related surface truth measurements.

Additional information concerning the hardware capabilities of Terminals 2 and 3 is contained in Reference 10.

3.3 Special Hardware

3.3.1 High Density Digital Tape (HDDT) Subsystem

The HDDT unit will be interfaced to the AOIPS PDP-11/70 in June 1977. It consists of a Honeywell Model 96 instrumentation tape recorder, a Martin-Marietta Data Converter, a Serial Controller Interface (SCI) fabricated by General Electric Company, and a DEC Model DR-70 Massbuss Adapter to operate the recorder on the AOIPS system.

The recorder uses one-inch wide magnetic tapes to record data on 10 of 14 data tracks. The remaining four tracks are utilized for time

tagging, audio, and two spares. The unit operates with data transfer rates of up to 20 megabits per second with bit error rates of 1 in 10^6, and provides for storage of approximately 1.4×10^{10} bits per 7200-foot reel of tape at a packing density of 20,250 bits per inch per data track.

Six playback speeds are provided, ranging from 120 inches per second to 3-3/4 inches per second. The unit will be operated at 7-1/2 inches per second for playback of data into the AOIPS yielding an input data rate of approximately 1.5 megabits per second.

A high-speed search capability is available at 120 inches per second; tape rewind occurs at 200 inches per second.

The Serial Controller Interface (SCI) provides the electronics needed to synchronize the serial input-output bit stream. The AOIPS SCI has been modified to subsample or average image data to allow selection of a portion of an image during data transfers to the AOIPS. This SCI capability provides options for obtaining subimages and reduced images from the full image data sets stored on high-density tapes.

Additional information about the HDDT subsystem and planned recording format restrictions is contained in Reference 11.

3.3.2 Video Switch-Disk Subsystem

The Video Switch unit was designed at Goddard Space Flight Center and contains a set of 100 single-pole/single-throw switches capable of video frequency response in the 0- to 30-megahertz range. The switches are used to route various video signals around the AOIPS complex. The Video Switch unit is controlled either manually or by the AOIPS PDP-11/70 computer.

The Video Disk unit is a Data Disk Corporation Model 3102 video disk and it is attached to the Video Switch unit. It stores up to 600 TV-sized frames, which may be recorded from or played back through the Video Switch unit to the AOIPS terminal displays, to an Advent large-screen TV projector, or to one of several video tape recorders. The Video Disk is controlled manually or by the PDP-11/70 computer. Computer control allows computer selection of image sequences for playback from or recording on the disk.

3.3.3 Image Recorder

A Dicomed Image Recorder, Model 162, is utilized as an offline device for producing hardcopy output products of images and images overlayed with data plots and contours. The recorder accepts standard 800-bit-per-inch, 9-track tape as input.

Dicomed input tapes are formatted so that each line of image data is terminated by a record gap and each image is contained in one file

terminated by a file mark. For color products, the image files are sequenced in a red image -- green image -- blue image order. A black and white image is contained in one file.

Normally, each line of data on a Dicomed tape contains up to 1024, 2048, or 4096 picture elements. The number of lines per image must be less than or equal to 4096.

The AOIPS Dicomed recorder has a character generator which requires a separate command file on the input tape to produce the desired annotation characters.

Software packages exist within the AOIPS to generate Dicomed input tapes with annotation files.

Output products include exposed black and white film (Kodak 4142), Polaroid (Types 52 and 58), or color film (Kodak 6115 positive and 4107 negative). The 6115 film is used for reproductions in reports, the 4107 for photographic prints, and Aerocolor roll film for large production jobs.

3.3.4 Microdensitometer

A Photometric Data Systems Model 1050 microdensitometer is used as an offline device to quality check Dicomed and other film output products.

4. AOIPS SOFTWARE DESCRIPTION

Numerous software packages are available on AOIPS; some are geared to the specific requirements of an application and some are of a general support nature. Figures 11 and 12 present an overview of the major software packages available on Terminals 1 and 2 respectively. A discussion of the capabilities of each package is contained in the following subsections.

4.1 Operating System Environment

Both the PDP-11/45 (Terminal 1) and the PDP-11/70 (Terminal 2) operate under the DEC-supplied RSX-11D operating system. Some major characteristics of this system are as follows:

- Multiprogramming; multiple tasks are scheduled by priority.
- Intertask communication is supported through event flags and variable-length messages.
- The maximum size of any task is 32K 16-bit words.
- File structures on disk are based on 256-word blocks.

The PDP-11/45 is currently operating under Version 6a of the system and the -11/70 uses Version 6b; however, the differences are invisible to the user.

RSX-11D OPERATING SYSTEM

	IMAGE 100 EXECUTIVE SOFTWARE	METEOROLOGY SOFTWARE – METPAK –	CLASSIFICATION SOFTWARE – CLASSPAK –	AOIPS SUPPORT PACKAGE – ASP –	AIRCRAFT SENSOR ANALYSIS PACKAGE – ASAP –	WATER RESOURCES DATA MANAGEMENT SYSTEM	DICOMED OUTPUT PACKAGE – DICOPAK –
DATA INPUT:	LANDSAT CCT NOAA SMS CCT AOIPS CCT LARS CCT SMIPS/VICAR CCT JSC UNIVERSAL FORMAT METPAK DISK FILES	NOAA SMS CCT AOIPS SMS CCT DISK FILES	LANDSAT CCT AOIPS CCT	LANDSAT CCT AOIPS SMS CCT AOIPS CCT METPAK DISK FILES PUNCHED CARDS	HCM/CZCS AIRCRAFT CCT SMIPS/VICAR CCT	LANDSAT CCT SMS CCT DIGITAL TOPOGRAPHIC DATA AOIPS CCT POINT MEASUREMENT DATA BOUNDARY MAPS OHSER CCT DIHS RECTIFIED IMAGE TAPE	IAT REFRESH MEMORY CLASSPAK DISK DATA SETS OHSER DATA CARDS
PREPROCESSING:	LANDSAT OVERVIEW SCALED CURSOR GENERAL PURPOSE TRANSFORM WINDOW DISPLAY TIME LAPSE DISPLAY	IMAGE OVERVIEW IMAGE ZOOM/REDUCE IMAGE REGISTRATION IMAGE NAVIGATION TIME LAPSE DISPLAY CURSOR	LANDSAT OVERVIEW GREY LEVEL PRINTOUT CURSOR	IMAGE OVERVIEW IMAGE ZOOM/REDUCE GENERAL IMAGE DISPLAY SCALED CURSOR GREY LEVEL PRINTOUT	IMAGE OVERVIEW IMAGE ZOOM/REDUCE IMAGE SCROLL DISPLAY IMAGE RECTIFICATION IMAGE TRANSLATION IMAGE MIRRORING	CONTRAST ENHANCEMENT IMAGE ZOOM/REDUCE 2D PERSPECTIVE OF 3D DATA POINT SOURCE DATA INTERPOLATION EIGENVALVE ANALYSIS WMO GRID OVERLAY POLYGON OVERLAY/DISPLAY EDGE ENHANCEMENT	ASPECT RATIO CORRECTION IMAGE AREA SELECTION THEME EDITING COLOR ASSIGNMENT
PROCESSING:	SIGNATURE ACQUISITION SIGNATURE ANALYSIS HISTOGRAMS CLASSIFIER TRAINING CONTRAST STRETCH LEVEL SLICE THEME MANIPULATION RATIO IMAGES	CLOUD TRACKING	TRAINING/TEST SITE SELECTION INTERACTIVE EDIT OF TRAINING AND CLASSIFICATION RESULTS HISTOGRAMS	HISTOGRAMS PSEUDOCOLOR CONTRAST STRETCH IMAGE COMBINATIONS STATISTICS	HISTOGRAMS PSEUDOCOLOR CONTRAST STRETCH SIGNATURE ACQUISITION	HISTOGRAMS DATA BASE CREATION IDENTIFY DATA BASE ELEMENTS WITHIN A POLYGON LINK DATA BASE ELEMENTS WITHIN A POLYGON INPUT SMS CLOUD POLYGONS CREATE PRECIPITATION MAPS REGISTER IMAGES TO DATA BASE	BLACK AND WHITE IMAGES FALSE COLOR COMPOSITES THEME MAPS ANNOTATION
ANALYSIS:	PARALLELEPIPED CLASSIFICATION THEME AREA	CLOUD MOTION/DYNAMICS WIND FIELD GENERATION CLOUD HEIGHT CLOUD TEMPERATURE	MAXIMUM LIKELIHOOD CLASSIFIER CLASSIFY TEST SITES	NONE	SPECTRAL PLOTS	NONE	NONE
DATA OUTPUT:	VIDEO FILE THEME FILE THEME PRINT SAVE TAPES DISK FILES PRINTOUT DICOMED FILES	AOIPS SAVE TAPES DISK FILES DICOMED FILES PRINTOUT	THEME PRINT STATISTICS PRINT DICOMED FILES DISK FILES SAVE TAPE AOIPS SMIPS CCT	PIXEL LIST HISTOGRAM PRINTOUT DICOMED FILES AOIPS SAVE TAPES	PRINTOUT DICOMED FILES	SHADE PRINT MAP BINARY POLYGON MAP IMAGE FILES THEME FILES DATA BASE THEME OVERLAYS PERSPECTIVE PLOTS HISTOGRAMS DICOMED FILES DATA BASE TAPE	DICOMED TAPES
INTERFACE TO	METPAK ASP LARSYS SMIPS/VICAR	ASP IMAGE 100 SYSTEM	DICOPAK SMIPS/VICAR	METPAK DICOPAK SMIPS/VICAR IMAGE 100 SYSTEM	NONE	NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM CRIES (COMPREHENSIVE RESOURCE INVENTORY AND EVALUATION SYSTEM)	CLASSPAK ASP

Figure 11. AOIPS Terminal 1 Software Overview

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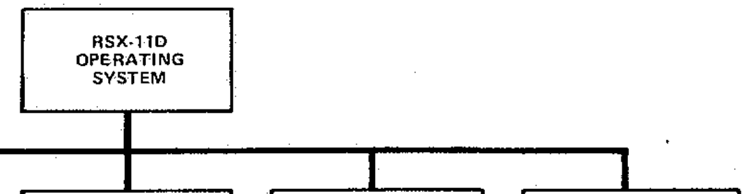
OF POOR QUALITY



	METEOROLOGY SOFTWARE – METPAK –	AOIPS SUPPORT PACKAGE – ASP –	TERMINAL 2 TEST SOFTWARE – TESTPAK –	DICOMED OUTPUT PACKAGE – DICOPAK –	DATA PLOTTING SOFTWARE – PLOTPAK –
DATA INPUT:	NOAA SMS CCT AOIPS SMS CCT DISK FILES PUNCHED CARDS	LANDSAT CCT AOIPS SMS CCT AOIPS CCT METPAK DISK FILES PUNCHED CARDS	TEST IMAGES TEST PROCEDURES TEST PATTERNS DISK DATA SETS	IAT REFRESH MEMORY CLASSPAK DISK DATA SETS ORSER DATA CARDS	INPUT FROM CALLING PROGRAM
PREPROCESSING:	IMAGE OVERVIEW IMAGE ZOOM/REDUCE IMAGE REGISTRATION IMAGE NAVIGATION TIME LAPSE DISPLAY PSEUDO COLOR DISPLAY CURSOR	IMAGE OVERVIEW IMAGE ZOOM/REDUCF GENERAL IMAGE DISPLAY SCALED CURSOR GREY LEVEL PRINTOUT	COLOR ASSIGNMENT HARDWARE SET UP LOOKUP TABLE GENERATION	ASPECT RATIO CORRECTION IMAGE AREA SELECTION THEME EDITING COLOR ASSIGNMENT	GENERATE DATA PLOTS GENERATE DATA CONTOURS GENERATE MAP GRIDS ANNOTATION CONTINENTAL OUTLINES
PROCESSING:	CLOUD TRACKING LEVEL SLICING TABLE LOOKUP ENHANCEMENT DATA PLOTS/CONTOURS IMAGE OVERLAY DISPLAYS	HISTOGRAMS PSEUDOCOLOR CONTRAST STRETCH IMAGE COMBINATION STATISTICS	TEST OF ALL HARDWARE SET UP AND PROCESSING FUNCTIONS	BLACK & WHITE IMAGES FALSE COLOR COMPOSITES THEME MAPS ANNOTATION	
ANALYSIS:	CLOUD MOTION/ DYNAMICS WIND FIELD GENER-ATION CLOUD HEIGHT CLOUD TEMPERATURE WIND FIELD ANALYSIS		DEFINES PROBLEM AREAS AS RESULT OF TESTS		
DATA OUTPUT:	AOIPS SAVE TAPES DISK FILES DICOMED FILES PRINTOUT IMAGE OVERLAYS PLOTS/CONTOURS	PIXEL LIST HISTOGRAM PRINTOUT DICOMED FILES SAVE TAPES	TEST RESULTS TV DISPLAYS PRINTOUTS	DICOMED TAPES	PRINTER PLOTS TV DISPLAYS DICOMED TAPES
INTERFACE TO:	ASP TESTPAK DICOPAK PLOTPAK	METPAK DICOPAK SMIPS/VICAR	METPAK ASP	METPAK ASP	METPAK

Figure 12. AOIPS Terminal 2 Software Overview

The user interface to the operating system is through Monitor Console Routine (MCR) commands. Functions provided through these commands include:

- Log on (HEL) and log off (BYE)
- Data set copying and directory listing (PIP)
- Task initiation (RUN) and abort (ABO)
- System status monitoring (SYS)

Further information on the RSX-11D operating system may be found in Reference 12.

An AOIPS applications package is initiated by typing the RUN command to start an executive task for that package. This executive task requests other tasks as necessary to perform user-selected functions.

All AOIPS applications packages interface with the user through a hierarchical structure of menus. At any stage of processing, the user is presented with a numbered list (menu) of processing operations available. The user selects an option from the menu by typing in the number corresponding to that option. The result of the selection will be either the displaying of the next menu level of options or the execution of an applications task to perform a specific function.

4.2 Terminal 1 Applications Packages

Terminal 1 (the Image 100) was delivered with an applications package (the Image 100 software system) designed for interactive multispectral classification of Landsat data. To support the various requirements of AOIPS users, several additional packages were developed for Terminal 1. A brief description of each of these packages follows.

4.2.1 Image 100 Software System

This package is primarily oriented toward multispectral classification using single cell and multicell parallelepiped techniques. Some enhancements and modifications to the delivered software have been performed by Goddard Space Flight Center personnel. A functional overview of the processing capabilities included in the Image 100 software system is shown in Figure 13.

Further information on the Image 100 system software is included in References 9 and 13.

4.2.2 Meteorology Package (METPAK)

METPAK is an interactive menu driven system which provides image navigation, registration, and other functions required to support cloud motion and wind vector field analysis. Input images must be AOIPS format tapes or reside in the METPAK image data base.

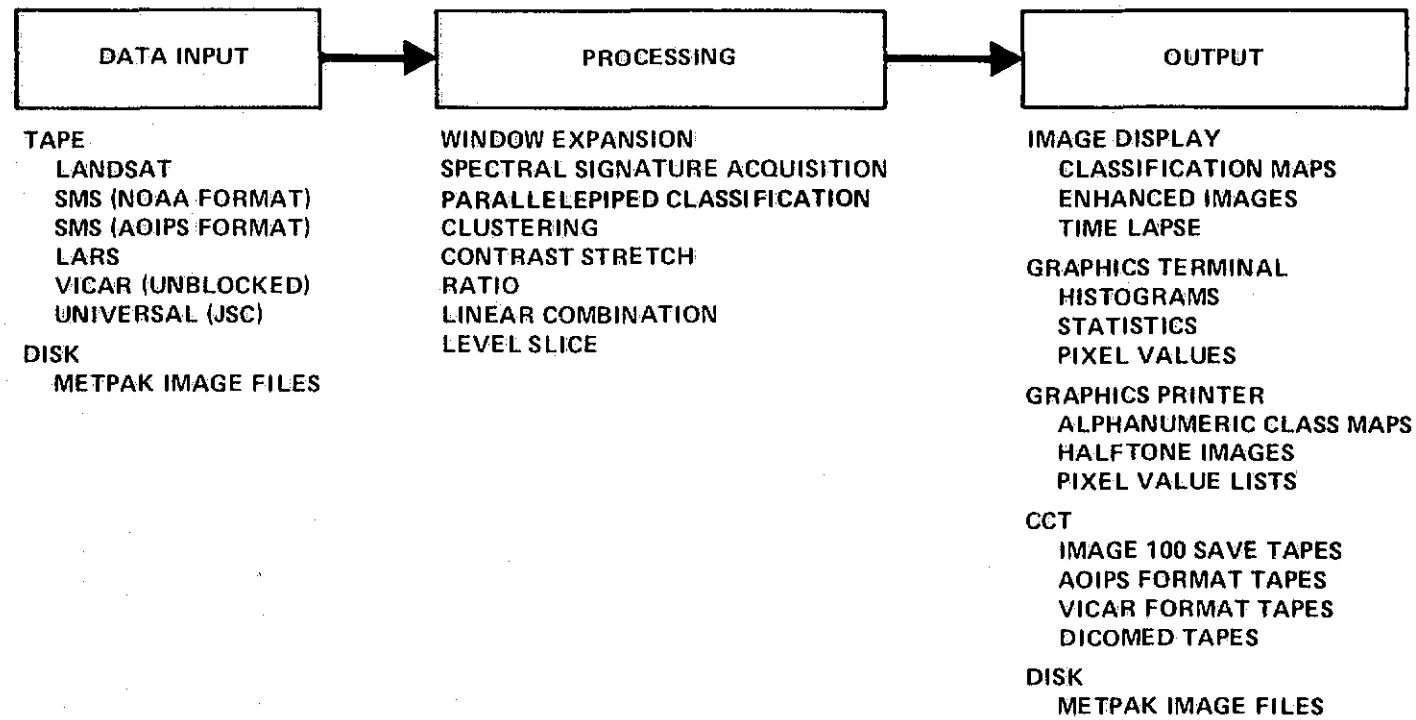


Figure 13. Image 100 Software Overview

METPAK functions for cloud tracking to generate wind vectors are as follows:

- Establish latitude and longitude of selected clouds to accurately measure cloud position change between images.

- Compute wind vectors from the displacement of the selected clouds.

- Compute cloud height.

- Display the wind vector field for evaluation and interactive modification.

- Provide printer output for direct analysis and magnetic tapes of wind vectors for plotters and hardcopy image generation systems.

METPAK output tapes include processed images in AOIPS or Dicomed format and wind vector field tapes for input to analysis programs run on a S/360-91 computer.

Additional information about METPAK is contained in Reference 14 and in Section 5.1.

4.2.3 Classification Package (CLASSPAK)

CLASSPAK is a menu driven maximum-likelihood classification package. Some significant features of this package are outlined below:

- Accepts Landsat CCTs or AOIPS standard format tapes as input.

- Allows user selection of area and channels to be extracted from the input tapes and stored on disk for processing.

- Allows up to 24 channels of data to be input; allows statistical analysis of all channels input; performs classification using up to 8 channels.

- Derives class statistics from training sites or card input.

- Provides a maximum of 25 training/test classes, with up to 25 sites per class.

- Displays class correlation and covariance matrices.

- Provides capability to write statistics and master image data to tape in AOIPS format for input to the SMIPS/VICAR classification programs.

- Provides a highly flexible, interactive environment for selecting, defining, displaying, editing, and combining training sites and training site statistics.

Further information about CLASSPAK is contained in Reference 15.

4.2.4 Aircraft Sensor Analysis Package (ASAP)

ASAP is an interactive software system designed for processing multichannel radiometer data acquired from aircraft flights. This system is currently used to process Heat Capacity Mapper and Coastal Zone Color Scanner aircraft data. Some of the major functions of this package are outlined below.

- Displays up to 5 channels in either an overview or incremental scan mode.
- Performs input to refresh memory of up to five channels for a user-specified segment.
- Performs image rectification to correct for scan angle distortion.
- Performs image mirroring and translation to a user-specified reference point for flight path correction.
- Acquires histograms for user-specified areas.
- Performs piecewise linear and power contrast stretch.
- Generates a pseudocolor display from a single-channel image.

Input data is accepted from calibrated aircraft tapes and from labeled or unlabeled SMIPS/VICAR format tapes.

Output tapes in Dicomed (unlabeled SMIPS/VICAR) format may be produced.

Additional information on ASAP is contained in Reference 16.

4.2.5 Water Resources Data Management System

This is a geocoded data base/data management system designed for hydrological investigations. The system currently accepts Landsat, SMS, and topographic data. Planned expansion of its capabilities will allow input of historic ground truth, weather station data, and stream gage information to its data base. All input data is registered to the World Meteorological Organization (WMO) grid at one-square-mile cell resolution. Two types of data files are maintained: cell archive for slowly varying information and cell daily for rapidly varying information. Functions are available for editing, displaying, and overlaying these data files.

Information from the cell-level files may be aggregated to form subbasin level archive and daily files, where subbasins are polygons defined by the latitude and longitude coordinates of the WMO grid vertices. The subbasin level data is suitable for input to various hydrological models.

Prior to use of this system, Landsat data and/or SMS data must be loaded into the refresh memory of Terminal 1 using the Image 100 software system or METPAK, respectively.

Further information on this package may be found in Reference 17.

4.2.6 Dicomed Output Package (DICOPAK)

DICOPAK produces an output tape of one of the following for input to the offline Dicomed film recorder:

- Terminal refresh memory contents
- Classified maps stored on disk (CLASSPAK output)
- Classified images stored on cards (ORSER output)

Image files are produced for black and white or color images. The user selects options for aspect ratio correction, theme selection, theme color assignment and image annotation.

Further information on this package may be found in Reference 18.

4.2.7 AOIPS Support Package (ASP)

ASP is a menu-driven, interactive system which provides the user with general image display and manipulation capabilities. Its purpose is to augment the special purpose functions of the other software packages. The major features of ASP are outlined below.

- Inputs image data from Landsat and AOIPS-format SMS CCTs, and from METPAK image data sets on disk.

- Displays user-selected images or expanded subimages (using pixel replication).

- Outputs tapes in AOIPS standard format and for the Dicomed image recorder.

- Dumps pixel values for a user-specified area.

- Displays histograms for user-specified areas.

- Performs pseudocolor, contrast stretch, and image combination.

All operations are performed on images stored on disk. All image selection, creation, deletion, input, and output operations are performed through a common data management interface.

Further information on this package may be found in Reference 19.

4.3 Terminal 2 Applications Packages

Unlike Terminal 1, no applications software was delivered with Terminal 2. Packages currently available on Terminal 2 were developed at Goddard Space Flight Center and are described in the following subsections.

4.3.1 Terminal 2 Test Package (TESTPAK)

TESTPAK is a package for diagnostic testing of Terminal 2 hardware. Through interactive menu selections, the user is able to individually exercise each of the hardware functions available. Although this package is not generally used for image analysis, it does provide capabilities for performing specific hardware functions that may not be available in the other packages. Reference 20 presents further information.

4.3.2 Meteorology Package (METPAK)

This package is basically the same as METPAK on Terminal 1. See Section 4.2.2. However additional analysis capabilities are provided to input nonuniformly gridded wind vector fields and to produce an interpolated, uniformly gridded output wind vector field. The Terminal 2 METPAK software also provides capabilities for calculating divergence, vorticity, stream functions, and approximately 20 other parameters from the uniformly gridded wind vector fields. Capabilities are provided for displaying plots and contours of derived parameters on the Terminal 2 TV displays and for Dicomed output products. Reference 21 includes further information on these capabilities.

4.3.3 AOIPS Support Package (ASP)

This package is basically the same as ASP on Terminal 1. See Section 4.2.7.

4.3.4 Dicomed Output Package (DICOPAK)

This package is basically the same as on Terminal 1. See Section 4.2.6.

4.3.5 Plot Package (PLOTPAK)

PLOTPAK provides capabilities for producing data plots and contours which are output to the Terminal 2 displays, to the PDP-11/70 printer or to Dicomed output tapes. Reference 22 presents further information on PLOTPAK.

4.4 Image Transfer Between Applications Packages

Images may be transferred between applications packages in any of the following three ways:

- Output images in refresh memory channels which were generated by one package may be acceptable input for certain other packages.
- Tapes generated by some packages may be read by others.
- Images on disk output by one package may be readable by other packages.

Table 2 shows the acceptable input and output for each of the packages described on this section. It should be noted that the refresh memory may be used to transfer images between two packages only if both packages are run on the same terminal.

Table 2. Cross Reference of Inputs and Outputs for AOIPS Applications Packages

Applications Package	Terminal		Refresh Memory	Tape Formats							Disk Formats	
	#1	#2		AOIPS	VICAR	Landsat	SMS-NOAA	LARS	JSC Universal	Dicomed	METPAK	CLASSPAK
Image 100 System	X		I/O	I/O	I/O	I	I	I	I	I/O	I/O	
METPAK	X	X	I/O	I/O						O	I/O	
CLASSPAK	X		O	I	O	I				O		I/O
ASAP	X		I/O		I					I/O		
Hydrology DMS	X		I/O									
DICOPAK	X	X	I							O		I
ASP	X	X	O	I/O		I					I	
TESTPAK		X	I/O									

I = Acceptable input
O = Available as output

An effort to integrate and simplify the transfer of images between applications packages is being undertaken on both terminal systems. See Section 6, Future System Enhancements.

4.5 System Support Software

System support software is available on AOIPS to facilitate the development of new applications tasks. In general, this support software consists of subroutine packages which provide AOIPS programs with an interface to the image analysis terminals and peripheral devices described in Section 3. Brief descriptions of the available packages and references to more detailed information follow.

4.5.1 Terminal Interface Software

Software control of the image analysis terminals is provided at two levels. At the lower level, device handlers provide software control functions corresponding directly to the hardware features of the respective terminals. This level is only used directly by applications software when maximum flexibility and efficiency are required.

The more commonly used method of accessing the image analysis terminals is through Fortran-callable interface packages which then format requests for the device handlers.

There are two device handlers and associated interface packages for Terminal 1, one delivered with the Image 100 and one developed by Goddard Space Flight Center personnel. The device handler/interface package delivered with the Image 100 is described in Reference 23 and is only used by the Image 100 Software System described in Section 4.2.1. The GSFC device handler/interface package is used by all other application packages on Terminal 1 and provides additional features (multiple line video transfers, recognition of console switch interrupts, and asynchronous data transfers) for faster response and more efficient use of system resources. Further information on the GSFC-developed device handler and interface package may be found in References 24 and 25, respectively.

Terminal 2 software uses a single device handler and interface package described in Reference 26.

4.5.2 ASP Data Management Interface

Subroutines are available on both terminals for interfacing applications programs with the ASP data management system. Although differences between the terminals require different versions of this package, the high level interface provided is the same for both terminals. These subroutines are documented in Reference 27.

4.5.3 Utility Subroutines

Many subroutines and programs have been developed for AOIPS which are of a utility nature. Some of the more frequently used ones are described below.

- STUFF - This facility enables applications programs to issue MCR commands to the operating system. It has proved extremely useful in allowing the applications software to logically mount devices and otherwise configure the system, thus minimizing direct user interaction with the operating system (Reference 28).

- FSTVID - This package of Fortran-callable subroutines performs efficient disk and tape input and output, in many cases at speeds 2 to 10 times faster than standard Fortran I/O. (References 29 and 30).

- ERRMES - This package of error-handling subroutines enables the assembly language programmer to conveniently display I/O and system error messages. (Reference 31).

- HDDT Software - This package provides a series of Fortran-callable subroutines for testing and operating the High Density Digital Tape unit on AOIPS (Reference 32).

5. MAJOR AOIPS APPLICATIONS

During the past year, over 50 applications investigations have been supported on AOIPS. A partial listing of these investigations is contained in Appendix 4.

Table 3 summarizes the planned usage of AOIPS by discipline for fiscal year 1977.

5.1 Meteorology

The primary meteorological information extraction support provided on AOIPS is directed towards severe storm research investigations. The objectives of these investigations include deriving information from satellite and related ancillary data to improve the understanding of severe storm dynamics, to develop and enhance numerical prediction models of mesoscale phenomena, and to improve storm detection and prediction capabilities.

To date, meteorological investigations on AOIPS have concentrated on deriving information from geostationary satellite data for use in analyzing severe storm phenomena. Investigators analyze visible and infrared images from the Synchronous Meteorological Satellites (SMS-1 and -2) using the AOIPS METPAK software system. Cloud motions between spatially registered images are measured and wind vector fields are derived to study storm related phenomena. METPAK analysis programs are then used to generate uniformly gridded wind vector fields from the non-uniformly gridded wind fields derived

Table 3. AOIPS Usage Plan for FY 1977

Discipline	Terminal 1 (%)	Terminal 2 (%)
Oceanography	2	–
Meteorology	20	70
Earth Resources	36	5
Hydrology	25	4
HCMM/CZCS Aircraft	7	1
System Development	10	20
	100	100

Note: The AOIPS Usage Plan assumes two shifts a day, five days a week and one shift a day on weekends. Terminal 3 will be dedicated to meteorology applications.

from the satellite imagery. Computations are performed on the uniformly gridded wind fields to derive divergence, vorticity, and other useful parameters associated with the wind fields. The resulting information is combined with other meteorological information for input to various storm models and for further analysis by the investigators.

Figure 14 provides a more detailed view of a typical processing sequence used to derive wind fields. The meteorologist user has options to store input data on a system disk prior to the start of an analysis session or to read in the input data from computer compatible tapes at the start of a session. Once the input data is entered, the user reduces master SMS images

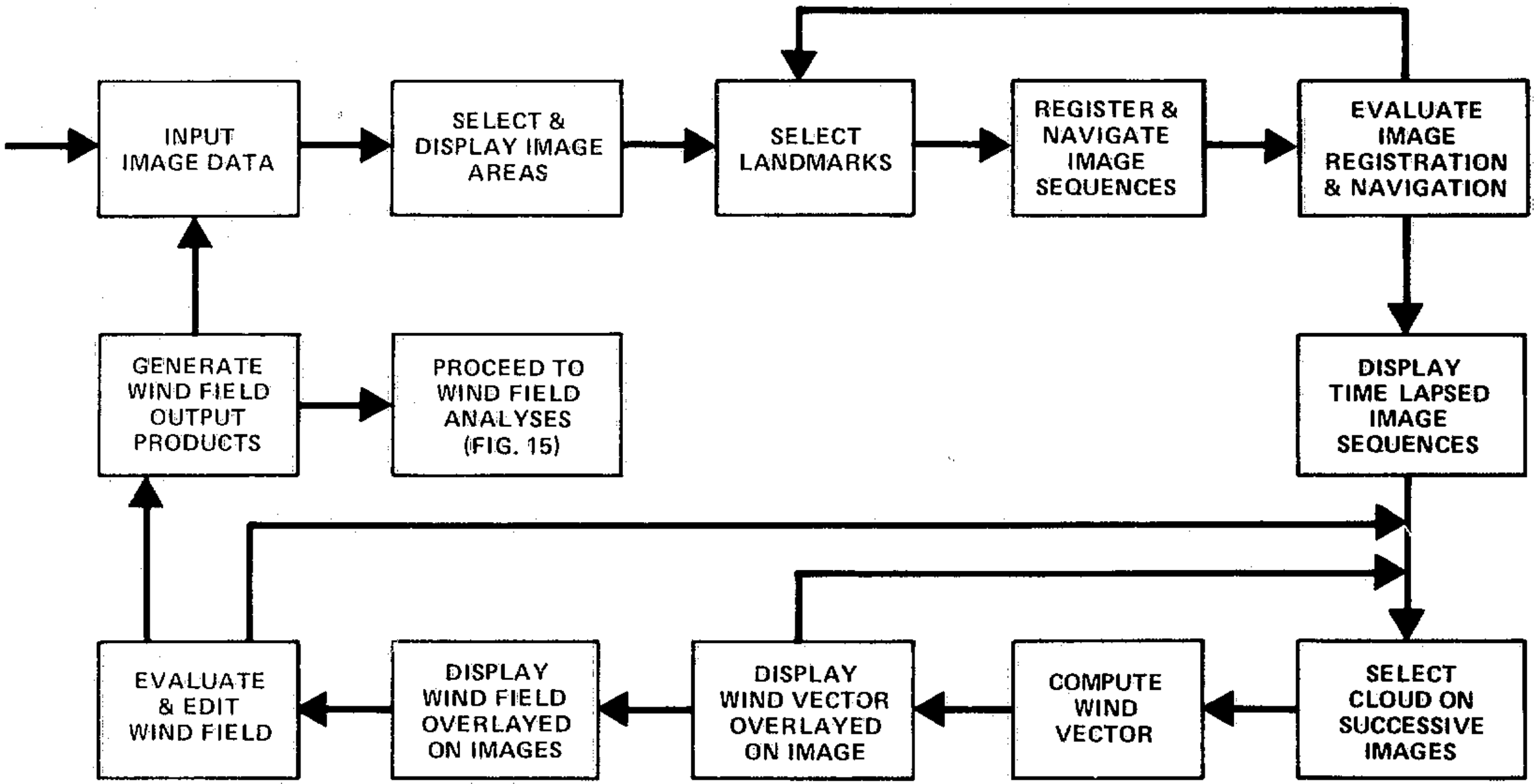


Figure 14. METPAK Wind Field Processing Sequence

to TV size for an overview display to select subimage areas for detailed processing. After selecting the subimage areas of interest, the system generates sequences of up to 5 TV sized images from up to 5 successive time intervals for each subimage area.

At this point, the user zooms in on image features to designate landmarks for image registration and navigation. The system utilizes the designated landmarks and the satellite orbit/attitude data to register the images in an image sequence and to provide coefficients for determining the latitude and longitude of any picture element in a selected subimage area.

The user displays and outputs navigation results to evaluate the registration accuracy achieved and iterates to select additional landmarks and recompute navigation parameters if necessary. When an image sequence has been registered and navigated, the system displays the sequence in a time lapsed movie loop presentation for initiation of cloud tracking operations. The user normally selects the same cloud element in successive frames of the time lapsed sequence.

Cloud displacement from frame to frame is computed from either manual selection of a cloud feature in successive frames or from the results of an automatic cloud position correlation algorithm. Once cloud displacement is determined, the navigation information is used to compute a wind vector.

Computed wind vectors are overlayed on the image sequence for evaluation by the meteorologist. The entire cloud tracking process continues until all of the desired wind vectors for an image sequence have computed. The resultant wind field is displayed as an overlay on the time lapsed image sequence for evaluation and editing. When a user is satisfied with the derived wind field, final output products are generated. At this point in the processing, a user either restarts the wind field generation process with a new input data set or a new image sequence or proceeds to analyze the derived wind field.

Figure 15 shows the processing steps used to analyze a derived wind field. During this process, the derived wind field is passed to METPAK analysis programs as a disk data set. The system displays the nonuniformly gridded input wind field and allows a user to edit and combine the input wind field with other existing wind data sets.

The edited wind field is used to generate a uniformly gridded wind field data set which is displayed as an image overlay for user evaluation and editing. At this point, the user may re-enter cloud tracking programs to derive additional wind vectors to fill in data sparse regions. When a satisfactory uniformly gridded wind field is produced, the system computes the divergence, vorticity and up to twenty other wind field parameters of interest to the investigator. (See References 14 and 21 for a listing of these parameters.) The resulting parameters are displayed as data plots and contours

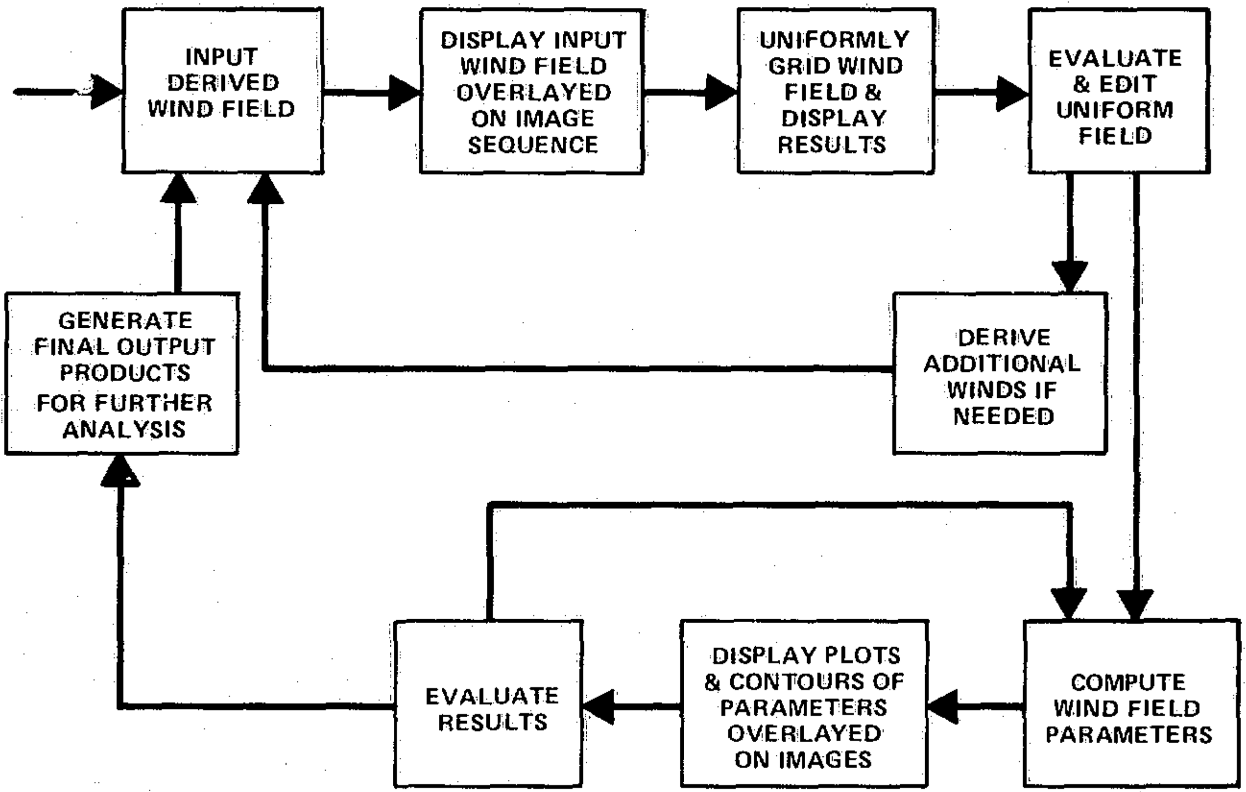


Figure 15. METPAK Wind Field Analysis Sequence

overlayed on images for evaluation prior to generating final output products for further analysis.

At various points in the entire METPAK wind field generation and analysis process, the user can request displays and printouts of intermediate results for evaluation and editing. The final system outputs - including printouts, image products, disk and tape data sets - are used for further postprocessing analysis by the meteorologist and for input to various severe storm models.

Sample output products of a wind field information data set and of images overlaid with input wind fields, uniformly gridded wind fields and data contours are presented in Figures 16, 17, 18 and 19.

Other AOIPS software is being used to develop techniques for monitoring and predicting severe local storms. Histograms of clouds in infrared images are obtained and ranges of brightness levels are displayed as themes. Cloud temperature and size variations in time are then studied. Reference 33 provides additional information on AOIPS support for meteorological investigations.

5.2 Oceanography

AOIPS support for oceanography is dedicated to determining sea surface temperature profiles and to studying sea surface temperature variations over periods varying from hours to days. Temporally spaced infrared images

CLOUD NO.	VECTOR ID.	U	V	SPEED (M/SEC)	DIRECTION (DEGREE)			HEIGHT (KM)	LATITUDE	LONGITUDE
1	1-2	-0.92	10.87	10.91	175.17	*	IMAGE1	2.80	40.7335	-96.5307
	2-3	1.38	14.16	14.23	185.58	*	IMAGE2	3.70	40.7629	-96.5340
	1-3	0.24	12.52	12.52	181.09	*	IMAGE3	3.60	40.8015	-96.5290
	3-4	0.00	0.00	0.00	0.00	*	IMAGE4	0.00	0.0000	0.0000
	2-4	0.00	0.00	0.00	0.00	*				
	1-4	0.00	0.00	0.00	0.00	*				
2	1-2	1.89	16.33	16.44	186.59	*	IMAGE1	4.80	40.6325	-96.4044
	2-3	-1.67	13.50	13.60	172.96	*	IMAGE2	5.00	40.6767	-96.3976
	1-3	0.10	14.91	14.91	180.40	*	IMAGE3	7.60	40.7135	-96.4036
	3-4	0.00	0.00	0.00	0.00	*	IMAGE4	0.00	0.0000	0.0000
	2-4	0.00	0.00	0.00	0.00	*				
	1-4	0.00	0.00	0.00	0.00	*				
3	1-2	6.39	20.21	21.20	197.55	*	IMAGE1	6.90	39.9107	-96.2126
	2-3	5.56	19.72	20.49	195.76	*	IMAGE2	7.50	39.9654	-96.1900
	1-3	5.98	19.97	20.84	196.67	+	IMAGE3	9.30	40.0191	-96.1702
	3-4	0.00	0.00	0.00	0.00	*	IMAGE4	0.00	0.0000	0.0000
	2-4	0.00	0.00	0.00	0.00	*				
	1-4	0.00	0.00	0.00	0.00	*				
4	1-2	5.65	15.96	16.93	199.50	*	IMAGE1	3.00	39.5541	-96.2484
	2-3	4.11	12.16	12.84	198.68	*	IMAGE2	4.10	39.5973	-96.2285
	1-3	4.88	14.06	14.88	199.15	*	IMAGE3	3.30	39.6305	-96.2140
	3-4	0.00	0.00	0.00	0.00	*	IMAGE4	0.00	0.0000	0.0000
	2-4	0.00	0.00	0.00	0.00	*				
	1-4	0.00	0.00	0.00	0.00	*				
5	1-2	4.31	15.62	16.20	195.42	*	IMAGE1	1.60	39.9852	-96.7007
	2-3	2.79	16.89	17.12	189.39	*	IMAGE2	1.50	40.0275	-96.6855
	1-3	3.55	16.25	16.64	192.31	*	IMAGE3	1.50	40.0735	-96.6755
	3-4	0.00	0.00	0.00	0.00	*	IMAGE4	0.00	0.0000	0.0000
	2-4	0.00	0.00	0.00	0.00	*				
	1-4	0.00	0.00	0.00	0.00	*				
6	1-2	2.02	18.78	18.89	186.14	*	IMAGE1	2.50	40.9048	-96.6446
	2-3	0.12	18.74	18.74	180.37	*	IMAGE2	3.60	40.9557	-96.6373
	1-3	1.07	18.76	18.79	183.26	*	IMAGE3	3.70	41.0067	-96.6369
	3-4	0.00	0.00	0.00	0.00	*	IMAGE4	0.00	0.0000	0.0000
	2-4	0.00	0.00	0.00	0.00	*				
	1-4	0.00	0.00	0.00	0.00	*				

Figure 16. Printout of METPAK Wind Field Data Set

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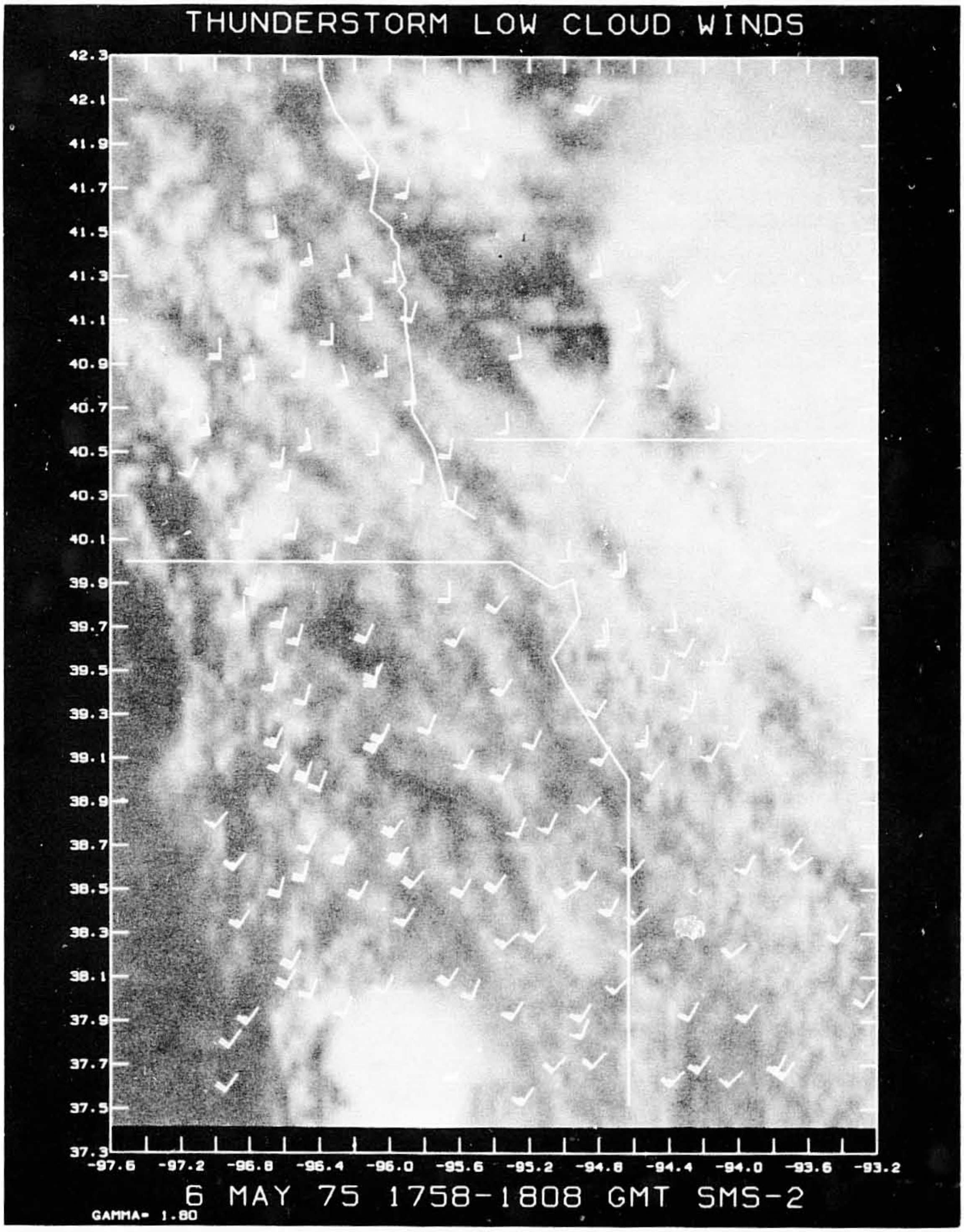

Figure 17. Dicomed Image of METPAK Derived Wind Field

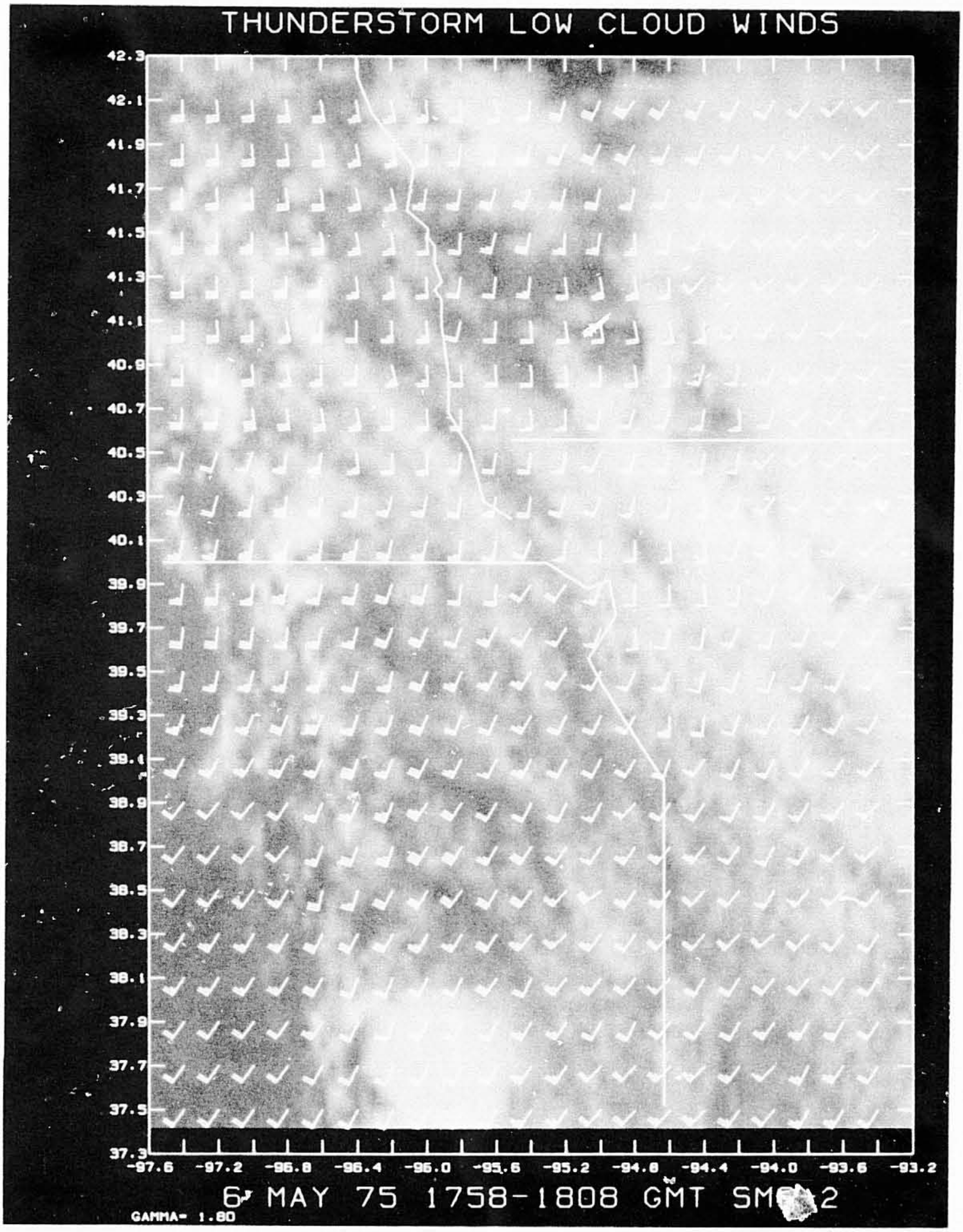

Figure 18. Dicomed Image of METPAK Uniformly Gridded Wind Field

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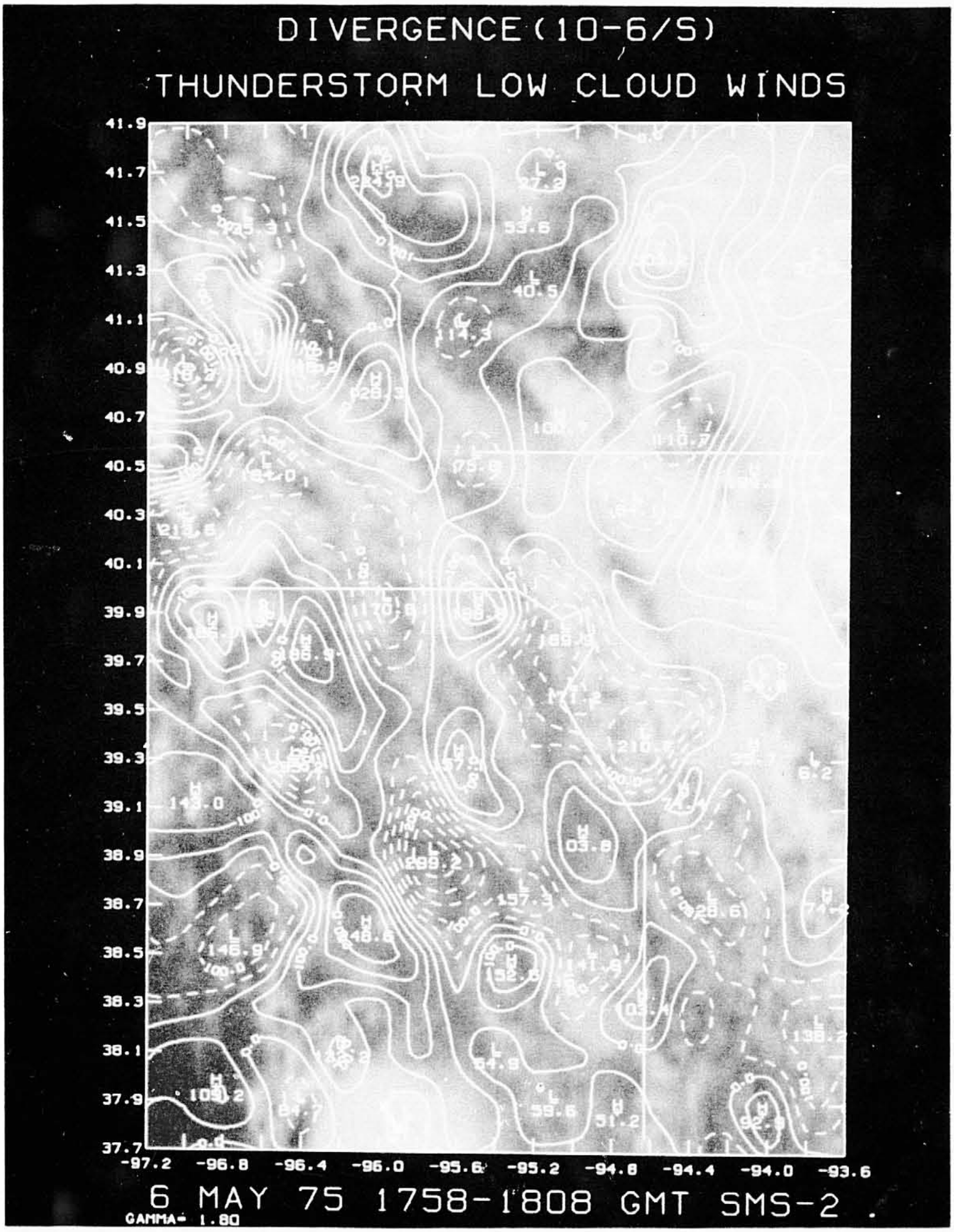

Figure 19. Dicomed Image of METPAK Derived Divergence Contours

from the SMS satellites are spatially registered. Intermediate image products are produced to represent the difference between pairs of input SMS images. These difference images are then contrast-stretched to facilitate subjective observation of the temperature variations.

5.3 Earth Resources

Most Earth resources investigations using the AOIPS Image 100 are performed in connection with the Information Transfer Laboratory (INTRALAB) at Goddard Space Flight Center. The general objective of this program is to apply existing technology to the solution of user-identified problems in remote sensing applications. This is accomplished through joint projects with industry and Federal, State, and local government agencies.

One such joint project, between INTRALAB and the U. S. Bureau of Census, is investigating the utility of Landsat Multispectral Scanner (MSS) data in delineating urban boundaries. MSS images are registered with 7.5-minute U. S. Geological Survey topographic maps and the urban boundaries, as determined by the 1970 census, are outlined. Residential and new construction areas adjacent to an urban boundary are classified, and an outer (urban fringe) boundary is defined. This urban fringe zone is then subdivided into census enumeration districts, and classification results for various land cover types are extracted within these districts. This information can then be used to update the urban boundary definition more frequently than the 10-year census period.

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In addition to the INTRALAB Earth resources work, several investigations in geology, agriculture, land use, forestry, and bathymetry are also supported on AOIPS.

Many Earth resources applications on AOIPS require classification analysis of multispectral data. Figure 20 describes the classification scenario common to these applications. Typically, a user enters his multispectral images into the AOIPS system by computer-compatible digital tapes.

Once his data is entered into the system, the user selects options from various system menus to store the data on system disks and in the refresh memories of Terminal 1. The user may request an overview image of an entire scene prior to selecting the TV-sized subimage of interest.

The preprocessing functions available including zooming or reducing images, ratioing images, contrast-stretching, and other related image processing functions. After selecting the desired preprocessing operations, the user enters a series of menus which allow him to define subimage areas for use in training the parallelepiped or maximum-likelihood classification algorithms.

Having defined a training site, the user defines the spectral signature of the training site by interfacing with programs which compile and display histograms of the grey level distribution of the training site.

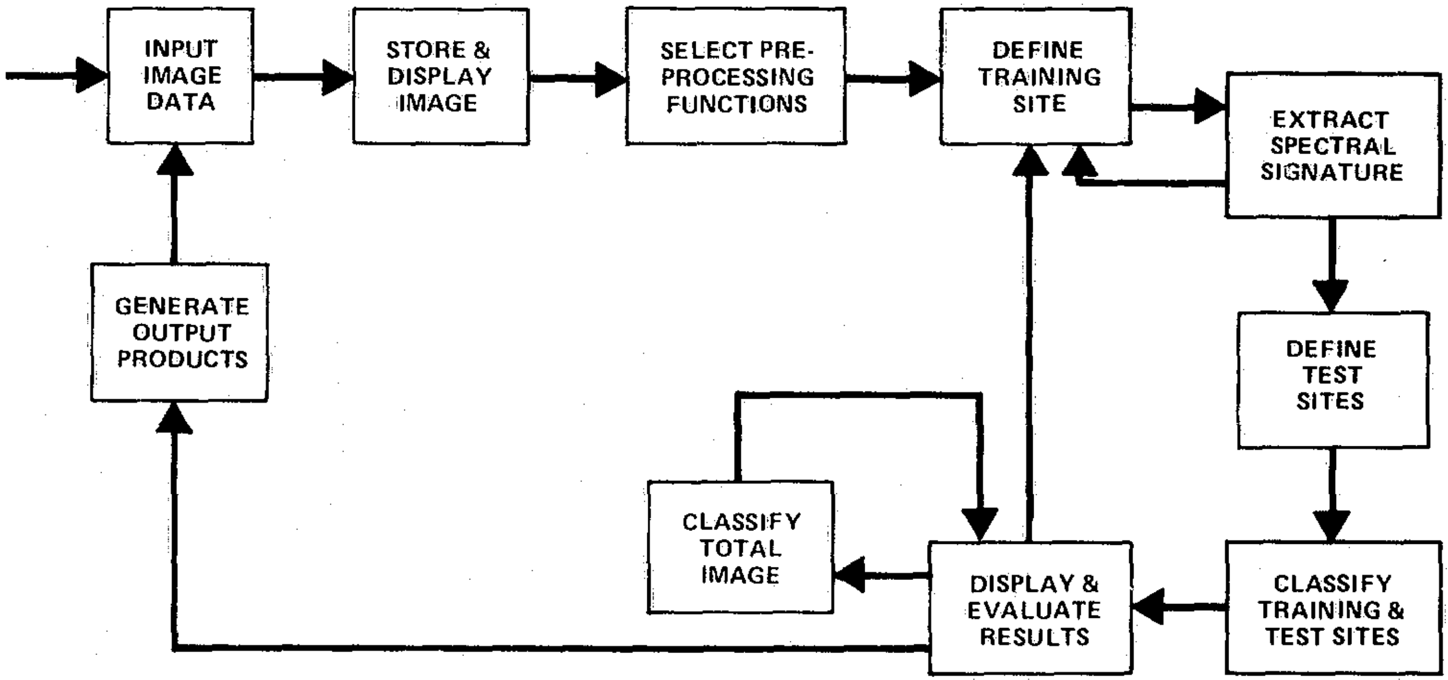

Figure 20. Image Analysis Terminal 1 Multispectral Classification Scenario

The user iterates on the training site definition operation until all of the desired training sites and spectral signatures have been defined. He than has the option of defining test subimages and classifying the training and test sites to evaluate performance of the classifier.

If he is dissatisfied with the classification results of the training or test site data, he may redefine, combine, or edit both the training and test site data prior to reclassification. When satisfactory classifier performance is achieved, the user classifies the total image of interest, evaluates the classification results, and, finally, generates output products of the classified image and of classification results.

A sample Dicomed output product of a classification map is presented in Figure 21.

5.4 Hydrology

A typical application of the AOIPS system in hydrology is concerned with classification of land use and ground cover characteristics in a watershed using Landsat MSS imagery. Initial classification is performed using a single-cell parallelepiped signature acquisition technique. Overlap pixels are then classified by examining clusters in plots of band 5 versus band 7, and defining rectangular classification decision boundaries. The percentage of each class in the watershed area is determined using a polygon cursor outline of the

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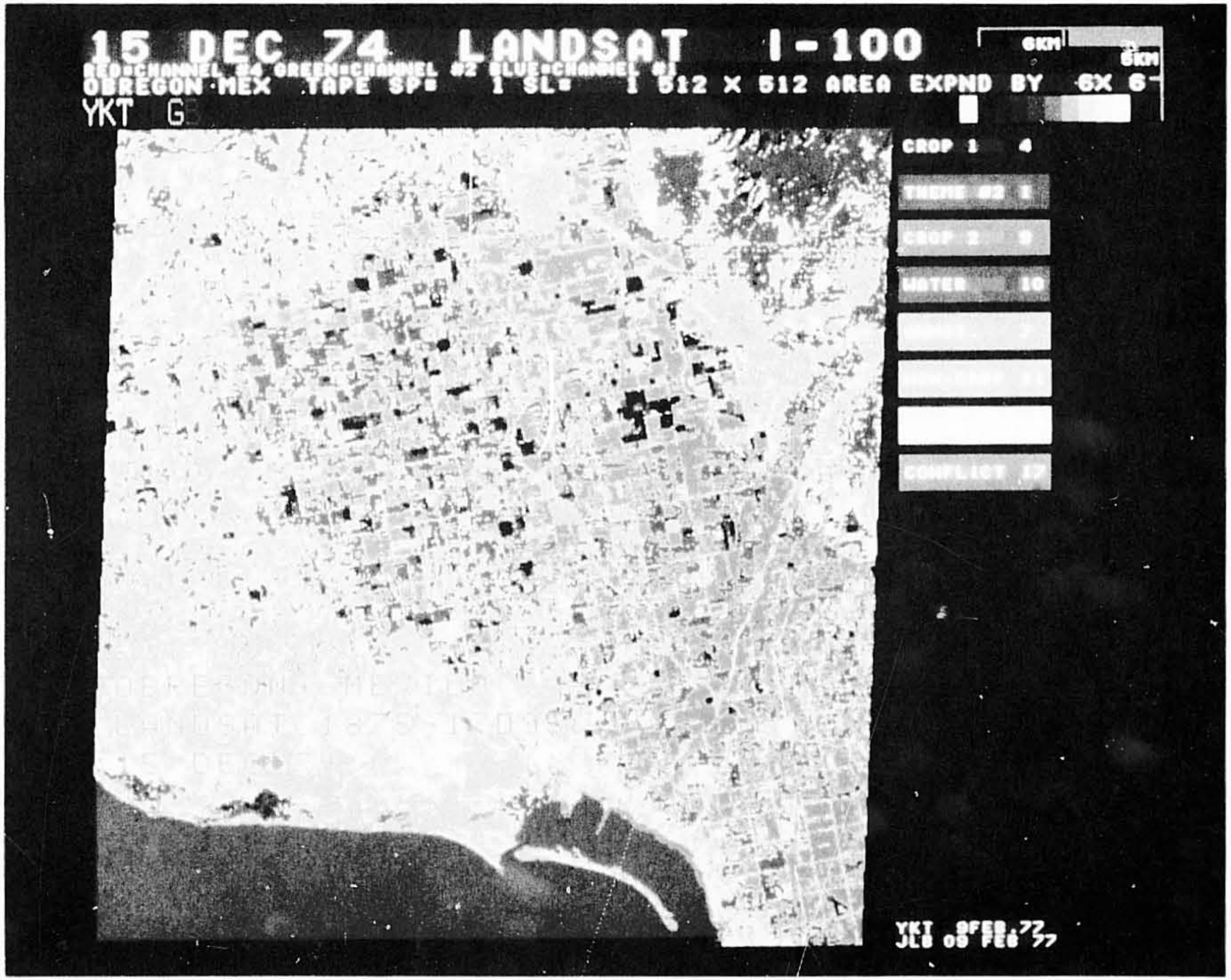


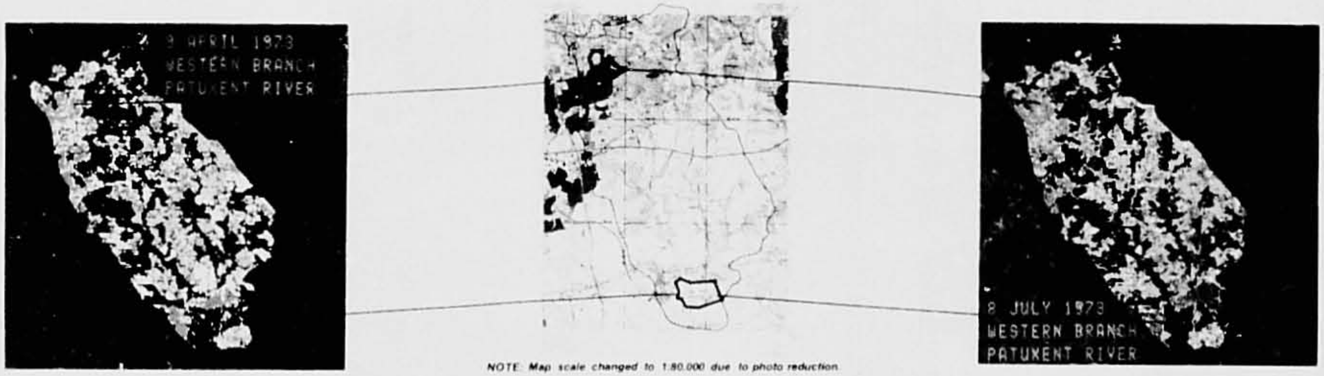
Figure 21. Dicomed Image of Classification Results

watershed. These percentages are then input to a watershed model to estimate storm water runoff.

Figure 22 presents a chart depicting output products and results for a hydrologic land use classification performed on AOIPS.

5.5 Aircraft Program Investigation

Recent activity in this area on AOIPS has mainly been directed toward development of the Aircraft Sensor Analysis Package (ASAP). Data from the aircraft versions of the Heat Capacity Mapper and the Coastal Zone Color Scanner will be used to simulate data from the satellite versions of these instruments and to develop processing algorithms needed to analyze the satellite data.



NOTE: Map scale changed to 1:80,000 due to photo reduction.

Imagery from Landsat-1 has been analyzed for hydrologic land use classification using the GSFC Atmospheric and Oceanographic Information Processing System (AOIPS). The upper portion of the Western Branch subbasin of the Patuxent River watershed served as a test site for classification. The boundary of this subbasin is identified on the 7½-minute USGS topographic map. The classification of Landsat image 1260-15201, 9 April 1973 and that of Landsat image 1350-15192, 8 July 1973 each resulted in cover type identification of greater than 90 percent of the watershed surface. These classifications (relative to the watershed boundary) are being used by the Hydrology and Oceanography Branch as input to hydrologic models for stormwater runoff estimation.

The AOIPS is a user-interactive computer system designed for analysis of remotely sensed earth resources information. Capabilities include various types of classification packages applicable to interpretation of data from ATS, Nimbus, GOES, ESMR, HCMM, side-looking radar, aircraft multispectral scanners and digitized photography as well as Landsat. The system rapidly analyzes Landsat and other imagery with results of each "training", or data sample classification, being displayed within seconds on the cathode ray tube for user evaluation and modification. Each of the final watershed classifications shown here was completed within twenty hours of system operation.

CLASSIFICATION RESULTS

CLASS	APRIL Hectares	APRIL Percentage	JULY Hectares	JULY Percentage
Agric fields	1116.8	15.5	2421.4	33.5
Construction	a		153.2	2.1
Water	23.0	0.32	18.7	0.26
Woodland	3194.9	44.5	2989.7	41.6
Residential	864.1	12.0	809.5	11.3
Urban	18.1	0.25	35.5	0.49
Bare fields	1297.2	18.1	281.4	3.9
Total classified	6495.8	90.7	6709.4	93.3
Watershed	7188.0		7188.0	

a. No classification for construction sites was attempted on the April image.

The table at the left contains area measurements for each of the landcover classes identified within the Western Branch subbasin. Also given is the percentage of the subbasin covered by each class. Note that the major difference between the two classifications is due to seasonal vegetation coverage changes. April's "bare fields" are classified as "agricultural fields" in the July image. The growth in riparian vegetation has caused a slight decrease in the surface of water exposed. Except for the fact that some of the urban surfaces were left unclassified in the April scene, there is a high degree of precision between the AOIPS classifications from two different images.

Figure 22. Hydrological Land Use Classification of Landsat Imagery

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6. FUTURE SYSTEM ENHANCEMENTS

6.1 Hardware Enhancements

The addition of Terminal 3 in April 1977 has already been noted. To fully support Terminal 2 and 3 operations, a 176-megabyte RP06 disk unit, 128K (16-bit) words of core memory, and two additional system printers will be installed on the AOIPS PDP-11/70 during 1977.

To facilitate severe storms research investigations, the AOIPS PDP-11/70 will be interfaced through a shared RP06 disk unit to another PDP-11/70 processor. This second processor will be dedicated to deriving atmospheric temperature and humidity profiles from GOES-D VISSR Atmospheric Sounder (VAS) data as part of the VAS Demonstration project. The shared disk link between the AOIPS and VAS 11/70s will provide the means of incorporating sounding data into severe storms analyses conducted on AOIPS.

Figure 23 shows a block diagram of the Application Programs Information Extraction System planned for implementation by early 1979. The Figure shows the present non-real time data acquisition system for acquiring SMS/GOES VISSR satellite data for severe storms research on AOIPS and a near-real time link for acquisition of GOES VAS data for analysis on the VAS PDP-11/70 processor. As indicated, the VAS processor includes an I^2S image analysis terminal and a 9.6K bps telecommunications link to the University of Wisconsin VAS processing system.

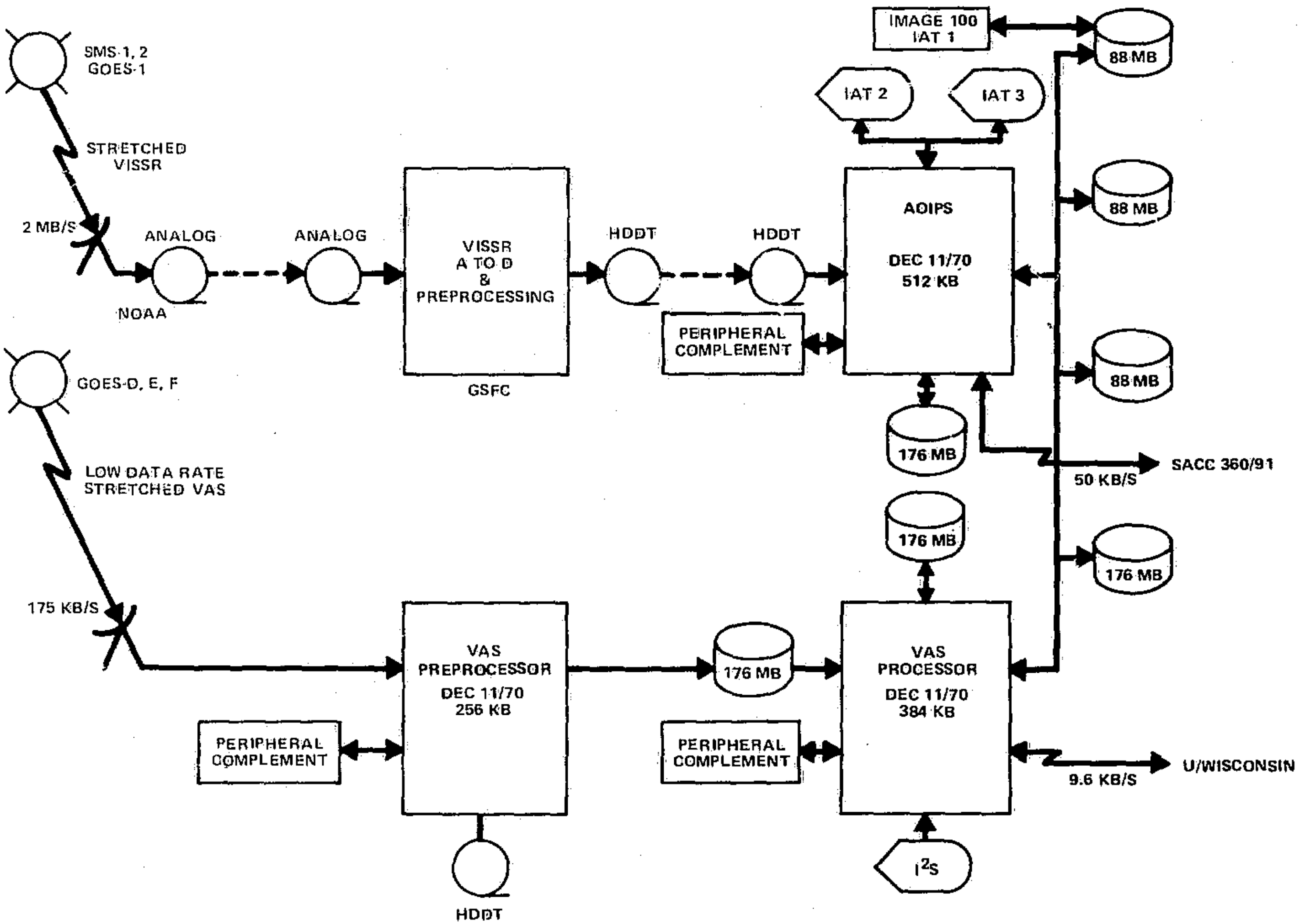

Figure 23. Application Programs Information Extraction System

6.2 Software Enhancements

The first phase of a design for an automated shared disk software package was completed in late 1976. The design provides for half duplex read and write operations between two PDP-11 processors using a dual ported RP04/RP06 disk unit under the RSX-11D operating system. Further information on the details of the problems involved in implementing such a package and on the software design are contained in Reference 34.

Future plans for enhancement of Terminal 1 software include continuation of efforts to integrate and consolidate all applications packages under Version 6B of the RSX-11D operating system. As a result of this effort, users will be able to easily switch from one application package to another through common disk and tape data sets.

The major planned system software enhancements for the AOIPS PDP-11/70 subsystem include developing data management capabilities to:

- Incorporate a wider range of nonimage surface truth and ancillary information into AOIPS information extraction operations.

- Provide capabilities for registering image and nonimage data from multiple sources.

- Establish integrated data bases for storage, comparison and correlation of multisource image and nonimage data.

- Establish data management interfaces between AOIPS data bases and various applications models.

- Integrate system capabilities and functional software packages to expedite the development of new applications software.

Efforts are underway to establish the requirements for needed AOIPS data management capabilities and to design a data management system which takes maximum advantage of existing software and which provides the capabilities listed above.

Major enhancements of the meteorology applications package, METPAK, are planned during the next two years. The new capabilities to be added to METPAK include:

- Enhancing capabilities for monitoring the dynamics of cloud formation and severe storm development.

- Developing precipitation estimation capabilities using several estimation techniques.

- Developing capabilities for multispectral analysis of severe storm data.

- Applying multispectral classification techniques to severe storm analyses.

- Incorporating Nimbus, ATS, METEOSAT, VAS, aircraft, and NOAA surface truth measurements into AOIPS information extraction processes.

- Implementing the Global Atmospheric Research Program (GARP) Level I, II and III data bases on AOIPS for use in severe storms research.

- Developing techniques to implement three dimensional objective analysis of wind vector fields and related meteorological information.

- Developing capabilities to interface AOIPS software with various meteorological models.

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GLOSSARY

AOIPS	Atmospheric and Oceanographic Information Processing System
ASAP	Aircraft Sensor Analysis Package
ASP	AOIPS Support Package
ATS	Applications Technology Satellite
bpi	bits-per-inch
CCT	Computer Compatible Tape
CLASSPAK	Maximum likelihood classification package
CRT	Cathode Ray Tube display
DEC	Digital Equipment Corporation
DICOPAK	Dicomed recorder output tape generation software package
DIRS	Digital Image Rectification System
DMA	Direct Memory Access
GOES	Geostationary Operational Environmental Satellite
GSFC	Goddard Space Flight Center
HCM	Heat Capacity Mapper
HDDTR	High Density Digital Tape Recorder
IAT	Image Analysis Terminal
JSC	NASA/Johnson Space Center
LARS	Laboratory for Applications of Remote Sensing
MCR	Monitor Console Routine

METPAK	Meteorology applications software package
MSS	Multispectral Scanner
NOAA	National Oceanic and Atmospheric Administration
OCS	Ocean Color Scanner
PLOTPAK	Data plot/contour software package
SCI	Serial Controller Interface (for HDDT unit)
SMIPS	Small Interactive Image Processing System
SMS	Synchronous Meteorological Satellite
TESTPAK	IAT 2/3 test software package
TV size	Images consisting of 512 lines by 512 picture elements per line
VAS	VISSR Atmospheric Sounder
VICAR	Video Image Communication And Retrieval System
VISSR	Visible/Infrared Spin Scan Radiometer
WMO	World Meteorological Organization

APPENDIX 1

AOIPS Image Label Format

This Appendix describes the format of the AOIPS image label record which is maintained by ASP image management.

The label is 256 computer words (512 bytes) long for compatibility with the TV line length, and is divided into three major fields: a 96-word Image Description field, a 72-word Applications Data field, and an 88-word System Directory field. The Image Description field (words 1-96) contains image identification, coordinate system parameters, and other specification flags needed for general image handling. See Table A.

The Applications Data field (words 97-168) may be used to carry data of significance only to a particular application software package. Table B gives, as an example, the content of this field on the SMS VISSR master tapes.

The System Directory field (words 169-256) is reserved for system information pointers related to the data in the file. For example, this field might contain pointers to descriptive annotation, graphic overlays, processing histories, calibration tables, histograms, orbit/attitude data, etc.

Table A

Sub-Field	16-bit Word No.	Content	Comment	
Character String	1	Image	8 character name of this image	
	2	Name	supplied by user when file is created	
	3	(8 ASCII	(truncated 16 char. name)	
	4	CHAR.)	ex: YUCATANI, WASH. M5	
	5	PARENT	8 character name of immediate	
	6	IMAGE	source image from which this image	
	7	NAME	was produced.	
	8	(8 CHAR.)	ex: ERTS CCT1	
Image Identification	9	MASTER	This 16-character master tape	
	10	IMAGE	I. D. is to be propagated without	
	11	TAPE	change to all images derived from	
	12	I. D.	this master, no matter how far	
	13	(16 CHAR.)	removed.	
	14			
	15			
	16			
UIC	17	IG	User	PDP11/RSX11D UIC = [IG, IU]
	18	IU		Group = IG, User = IU
			I. D.	Ex: IG = 1, IU = 350 [1,350]
Time	19	YYMM	Year*100+Mon	Master image start
	20	DDHH	Day*100+Hour	time to .0001 sec
	21	MMSS	Min*100+Sec	(binary) ex: 7508 1512 3456 7890 means: 15 AUG 1975 at 12:34:56: 7890 GMT
	22	FSEC	Millisec*10	

1-2

Sub-Field	16-bit Word No.	Content	Comment	
Format Codes	23	IAC	Access Code (= 0 for unrestricted, see Note 1)	
	24	IDAP	Applications I. D. Flag (1 = METPAK, 2 = CLASSPAK, 3 = ASP, etc.)	
	25	NDE	Number of System Directory Entries	
	26	Unused		
	27	LBLTYP	Label Type Code (= 0 for Standard Format, see Note 2)	
	28	ILC	Interleaving Code specifies file format (see Note 3)	
	29	"EF"	4 character VICAR keyword code	
	30	"IC"		
	31	IDPF	Image data pixel format (= 1 for 1 byte/pixel; see Note 4)	
	32	LRNOUT	Logical Ref. No. (File No.) used for output	
	33	NBYT	Record Length in bytes	
	34	NREC	File length = No. records	
	35	LEFT	Left edge fill in pixels	
	36	NTOP	Top edge fill in lines	
	37	NP	No. pixels of actual grey level image data	
	38	NL	No. lines of actual grey level image data	
Image Geometry	39	IZP	Initial zoom pixel	Physical coordinates (including edge) on parent image)
	40	IZL	Initial zoom line	
	41	MSP	Master start pixel	
	42	MSL	Master start line	
	43	IPFAC	Pixel zoom factor	Scale factors relative to parent image (+, increase; -, reduce)
	44	ILFAC	Line zoom factor	

Sub-Field	16-bit Word No.	Content	Comment
Image Geometry	45	IPN	Numerator (Pixel) — Cumulative scale factors of this image with respect to its original master image
Image Geometry	46	IPD	Denominator (Pixel) — Cumulative scale factors of this image with respect to its original master image
Image Geometry	47	ILN	Numerator (Line) — Cumulative scale factors of this image with respect to its original master image
Image Geometry	48	ILD	Denominator (Line) — Cumulative scale factors of this image with respect to its original master image
	49	IPO	Pixel offset
	50	ILO	Line offset
	51	LRNIN	Logical Ref. No. (File No.) used as input
	52	IZMT	Zoom type flag (= 0 for standard, see Note 5)
	53	IGEN	Generation of image (= 0 for masters, increment every generation)
	54	NUMSDR	No. of secondary data records included in top fill (see Note 6)
	55	LENSDR	Logical record length (in bytes) of top secondary rec.
	56	LRTDOC	Length of line documentation in right edge fill
	57	LEFDOC	Length of line documentation in left edge fill
	58	NUMBOT	Number of secondary data records in bottom fill
	59	LENBOT	Logical length of bottom secondary data records
	60	IDPROG	I. D. of program that produced this image
	61	NVERS	Version number of producing program
	62-87		Reserved (zero filled)
	88-96	FILE TIME	File creation time from system clock
	97-168	Applications Data	These words are reserved for storing data which are application dependent

Notes on Table A

Note 1. Access is indicated for members of the users organizational group and for the rest of the world. This word is divided into two bytes; the low order byte is for the owners organizational group and the highest order byte is for the world. The format for this byte is the lowest 4 bits indicated the allowed access for Read, Write, Extend, Delete where a 1 indicates not allowed (e.g., 0, 1, 1, 1 indicates Read only allowed); the upper 4 bits of each byte are zeros.

Note 2. The label type code in word 27 is reserved to flag possible variations in the label format, if unavoidable for future applications. Its purpose is to preserve flexibility. It should be set to zero for labels conforming to this baseline format.

Note 3. The interleaving code specifies the image file format. ILC = N-1 for N bands interleaved by line - thus a normal one band image would have ILC = 0 possible extensions are ILC = 100*(N-1) for N bands interleaved by pixel, and ILC = -32 for the fast video format in which the line index cycles in steps of 32 lines.

Note 4. The image data pixel format code can be indefinitely extended to accommodate new data types. The basic types suggested are:

IDPF =	1	Logical *1 (standard)
	2	Integer *2
	3	
	4	Real *4
	5	
	6	packed 6 bit data
	7	
	8	Complex *8 (for FFT)
	9	packed 9 bit data
	10	10 bit aircraft data in Integer *2 words

Note 5. The zoom type flag indicates the process by which this image was produced from its parent. IZMT= 0 implies a sampling reduce or a repeated pixel increase (depending on the sign of words 43-44). IZMT= 1 implies an averaging reduce or cubic convolution increase.

Note 6. Words 54-59 provide for the storage of related non-image data (e.g., extra labels) within the edge fill area if desired. Such data will be transferred with the image, without special bookkeeping, and will be available whenever the image is. Such secondary data records should begin on the top most line and left most pixel of the fill field they are contained in. The physical dimensions of the fill fields are still specified by words 33-38. The logical dimensions specified by words 54-59 indicate the presence of such data within the edge fill so that it can be preserved by general purpose image

processing routines. The contents of these logical records may be application specific.

Note 7. Directory Entries

Composed of 4 words, thus allowing 22 possible items to be related to an image. An entry includes the following: (1) item ID, (2) no. of records to item start location, (3) no. of records in item, (4) record length of item.

Table B. AOIPS-SMS VISSR Master Tape
Applications Data Field Format

16-Bit Word No.	Content	Comments
97	Band Code	1=Visible, 2=IR, 3=GRID
98	Pixel Width	No. of basic 1/2 mi. elements/ output pixel
99	Line Width	No. of 1/2 mi. sensor lines/ output line
100	Orbit/Attitude Flag	No. of O/A blocks in label (0 if none)
101	Calibration File	File No. of calibration data (0 if none)
102	Scaling Table ID	As defined in scaling program
103-104	Degree scalar = DSCL	Scale factor for orbit data angles = 2^{16}
105-106	KM Scalar = KSCL	Scale factor for orbit data (r, v) = 211
107-108	Day of year	1000*yr + day of orbit record (YYDD)
109-110	Millisec of day	(27 bits moved into 32 bit integer)
111-112	Attitude ID	From O/A tape
113-114	Latitude *DSCL	Geographic coordinates of satellite
115-116	Longitude *DSCL	
117-118	Height *KSCL	
119-120	Spin rt. ascen. *DSCL	

16-Bit Word No.	Content	Comments
121-122	Spin declination *DSCL	
123-124	Spin period (micro-sec)	
125-126	(Aries rt. ascen.) * DSCL.	
127-128	X * KSCL	Satellite position vector
129-130	Y * KSCL	(KM * KSCL)
131-132	Z * KSCL	
133-134	XDOT * KSCL	Satellite velocity vector
135-136	YDOT * KSCL	(KM/HR * KSCL)
137-138	ZDOT * KSCL	
139-168	(2nd O/A block, if available, same format as words 107-137)	

APPENDIX 2

AOIPS PDP-11/45 - Terminal 1 Equipment List

The AOIPS PDP-11/45 - Terminal 1 subsystem consists of the following hardware components:

- A General Electric Company Image 100 Image Analyzer Console with
  - color video display
  - hardware for image analysis functions including classification, ratioing and image transformations
- An INTEL Model IN-62 solid state refresh memory with
  - 5 refresh channels
  - 512 lines by 512 picture elements per refresh channel
  - 8 bit representation for each picture element
  - 10 MHz clock
- A Digital Equipment Corporation (DEC) central processing unit

including:

  - a PDP-11/45 Model FS processor
  - Model KT11-C Memory Management Unit
  - Model FP11-B Floating Point Unit
  - Model MF11-UP/MM11-UP core memory (128K words, 16 bits per word, 980 ns cycle time)

- Model BM873-YA bootstrap loader
- Model KW11-L real time clock

- Computer peripherals from DEC including:
  - A DR11-B Direct Memory Access (DMA) unit which connects the Image Analyzer Console to the PDP-11/45
  - An RK11-DE disk drive and controller (1.2 megawords storage, 180K bytes/sec transfer rate)
  - An RK05-AA disk drive (same characteristics as RK11-DE unit)
  - Two DL11-E display terminal interfaces
  - CR11 card reader (300 cards per minute)
  - DL11-C serial line interface (interconnects the AOIPS PDP-11/45 and -11/70 computers)
  - DEC writer Model LA36 (30 characters per second)
  - RWP04-CA dual port disk (shared with AOIPS PDP-11/70) 88 megabytes storage, 800K bytes per second transfer rate

- Additional peripherals including:
  - Two Bucode Model 4025-DD 9-track magnetic tape drives (125 inches per second, 800/1600 bpi)
  - Datum Model 5091-P11-DD tape drive controller
  - Gould Model 5000 line printer/plotter with PDP 11 interface (132 columns, 1200 lines per minute, 1024 dots per line)

- Tektronix model 4012 graphics display terminal (35 lines by 72 characters per line)
- Tektronix model 4610 hard copy unit (18 seconds per copy)

This entire subsystem, with the exception of the DL11-C and RWP04-CA units which interconnect this subsystem with the AOIPS PDP-11/70 subsystem, is available from GE with control and applications software as an Image 100 system.

APPENDIX 3

AOIPS PDP-11/70 - Terminal 2 Equipment List

The AOIPS PDP-11/70 - Terminal 2 subsystem consists of the following hardware components:

- A Hazeltine Corporation Model DDG 17 Image Analysis Terminal

including:

  - 5 solid state refresh memory channels
  - 512 lines by 512 picture elements per line per refresh channel
  - 8-bit representation for each picture element
  - color and black and white TV displays
  - rapid image processing operations using hardware lookup tables

- A Digital Equipment Corporation (DEC) central processing unit

including:

  - DEC PDP-11/70 UA processor with 300 ns basic CPU execution time
  - MJ11-AA/MJ11-AE core memory expansion giving a total of 256K words (16 bits) core memory. 400 ns effective cycle time (estimated time via 2K words of 240 ns cache memory)
  - Model FP-11C fast floating point processor
  - Model KW11-P programmable real time clock

- Computer peripherals from Digital Equipment Corporation as follows:
  - Two Model RWP04-AA disk drives and controller, 88MB capacity (each), 36 ms avg. access time, 800 KB/sec transfer rate (plus interface to a third RWP04 - see AOIPS PDP-11/45 terminal 1 equipment list)
  - Two Model TWU45-EA tape unit with controller and one Model TU45-EE tape unit - 9-track, 800/1600 bpi, 75 ips
  - Model LP11-VA line printer - 132 columns, 300 lpm
  - Model CR11 card reader - 300 cpm
  - Model VT05 alphanumeric CRT terminal with Model DL11-C interface - 72 columns x 20 lines, 5 x 7 dot matrix characters
  - Model VT55 graphics CRT terminal with Model DL11-C interface - graphics raster 512 x 236 points, alphanumeric 80 columns x 24 lines with 5 x 7 dot matrix characters, built in hard copy unit
  - Two Model VT50 alphanumeric CRT terminals with Model DL11-C interfaces - 80 columns x 12 lines, 5 x 7 dot matrix characters
  - Four Model VT52 alphanumeric CRT terminals with Model DL11-C interfaces - 80 columns x 24 lines, 5 x 7 dot matrix characters
  - Model GT42-AA graphics terminal with Model DL11-E interface - includes Model PDP-11/10 processor controller with 8K words of

memory, graphics raster 1024 x 768 points, alphanumeric 73 columns x 31 lines, 6 x 8 dot matrix characters and a Model H312-A null modem.

- Two Model DR11-B direct memory access units. One is for control interface to the Hazeltine DDG17 Image Analysis Terminal and the other is for control of the Matrix video switch and the Amcomp video disk units.
- Model DWR70 channel interface and model 7011725 CSS Direct Memory Access interface for high speed data transfers to the Hazeltine DDG 17 Image Analysis Terminal - 800 KB/sec transfer rates.
- Model DQ11-DA synchronous line module interface, E1A/CCITT termination, Model DQ11-AB error detection unit and Model DQ11-BB character recognition unit. This set of modules operates with a Bell Model 201 or equivalent modem to provide full duplex, 4800 baud communication interface to a remote IBM 360/91 large scale computer.
- Model DL11-C serial line interface (interconnects this subsystem with the AOIPS PDP-11/45 subsystem via a model DL11-C interface in that subsystem)

- High Density Digital Tape Unit includes a Honeywell Model 96 analog instrumentation tape unit, Martin-Marietta special electronics built under NASA Contract NAS 5-22821, and a General Electric serial controller interface built under NASA Contract NAS 5-23415 Mod. 5 - 20,250 bpi recording density, 14 tracks, 500K bits/sec to 20M bits/sec serial data rate.

- Hazeltine Corporation TV scanner is a peripheral of the Hazeltine DDG 17 Image Analysis Terminal in that it uses one of the terminals image refresh memories to store the scanner data. Will scan color or black and white hard copy products ranging in size from 2 x 2" to 32" x 32". The TV camera is of high quality using 525 lines with electronics capable of 900 line resolution. The camera video output is digitized to 256 discrete levels, however lens and camera noise considerably limit the grey scale resolution actually obtained. Software under development will increase the grey level resolution by averaging over a number of scan samples.

Other equipment in the AOIPS are:

- Dicomed Corporation Model D162 film recorder utilizes 9-track, 800 bpi tape unit input and produces color or black and white film output products.
  - 4096 x 4096 points full resolution, 2048 x 2048 points medium resolution, 1024 x 1024 points low resolution
  - 20 minutes to produce a full resolution black and white film product
  - produces 4 x 5 film or polaroid products

- Matrix Systems Corporation Model 6470 video switch - for routing video signals from and to various equipments.
  - 100 coaxial switches
  - interfaced to the PDP-11/70 for control via a DEC Model DR11-B DMA interface
- Telemation Model TCE 2000 video color encoder included to convert RGB to NTSCT standard video (used with the video switch)
- Data Disk Corporation Model 3102 video disk file and Model 3002 video disk controller
  - Stores 600 black and white images
  - Automatic looping through image sequences
  - Interfaced to the PDP-11/70 for control via a DEC Model DR11-B DMA interface
- Sony video cassette recorder Model VO-1800
- Sony Trintron color monitor CVM 1720 utilized with the Sony cassette recorder
- Ampex Corporation Model VR7000 black and white video tape recorder
  - Standard 1" video tape
- Ampex Corporation Model VR7800 color video tape recorder
  - Standard 1" video tape

- Advent Corporation Videobeam 1000A projection TV
  - color
  - standard video (modified to accept R, G, B video also)
  - 52" x 69" screen size
- Photometric Data Systems Corporation Model 1050 Microdensitometer
  - scanning rate up to 1440 mm/sec
  - density range 0 to 4, 0 to 100% transmission
  - X and Y axis precision of 5 microns
  - linearity ± 0.02 units of density, ± 0.5% transmission
  - 10" x 10" film size (max.)
  - black and white or color filters

APPENDIX 4

AOIPS Information Extraction Project Support

Applications Discipline	Investigation Title	GSFC Investigator	GSFC Branch Code
Oceanography	Sea Surface Temperature Determination	J. Price	913
Oceanography	Thermal Inertia Study Using SMS Data	J. Price	913
Meteorology	Omaha Tornado Outbreak Study	C. Peslin	911
Meteorology	1975 Northern Texas Tornado Outbreak	C. Peslin	911
Meteorology	Comparison of Low Level Satellite Derived Winds with Aircraft Measurements	F. Hasler	911
Meteorology	Use of Limited Scan SMS IR Data for Storm Anvil Expansion Studies	R. Adler	911
Meteorology	Use of Limited Scan SMS IR and Visible Data for Hurricane Intensification Studies	E. Rodgers	911
Meteorology	Simulated Satellite Stereoscopic Severe Storm Analysis	F. Hasler	911
Meteorology	Deriving Low Level Wind Fields for Input Into Mesoscale Severe Storm Forecasting Models	R. Adler	911

Applications Discipline	Investigation Title	GSFC Investigator	GSFC Branch Code
Meteorology	Evaluation of Wind Fields for Numerical Models	R. Adler	911
Meteorology	Technique Development for Cloud/ Thunderstorm Growth Monitoring	R. Adler	911
Meteorology	Tropical Cyclone Analyses Using Wind Field Derived From Short and Long Interval Satellite Imagery	E. Rodgers	911
Meteorology	Antecedent Conditions of Severe Local Storms	C. Peslin	911
Meteorology	Remote Sensing and Analysis of Dust Storms	R. Menzner	911
Meteorology	Effect of Various Time Intervals on Wind Determination from Limited Scan SMS Data	E. Rodgers C. Peslin	911
Forestry	North Carolina Forest Inventory	D. Williams	923
Land Use	Dismal Swamp Land Use Inventory	L. Shima	923
Hydrology	Patuxent River Watershed Hydrologic Land Use Study	J. Ormsby	923
Land Use	Federal Power Commission Power Line Routing	J. Christensen	923

Applications Discipline	Investigation Title	GSFC Investigator	GSFC Branch Code
Geology	Wyoming/Montana Geological Study	M. Podwysocki	923
Agriculture	LACIE Supersite Agricultural Analysis	J. Barker	923
Land Use	Census - Urban Area Delineation Study	J. Christensen	923
Hydrology	Water Management ASVT - Castro Valley Watershed	V. Salomonson	913
Landsat-D Study	Evaluation of Ocean Color Scanner and Landsat Data for Ocean Analysis	J. Barker	923
Heat Capacity Mapper	Registration of HCM Aircraft Day/Night Imaging	J. Price	913
Geology	Utah Aircraft Test Site Analysis	N. Short	923
Hydrology	Use of Synthetic Aperture Radar for Soil Moisture Determination	A. Chang T. Schmugge	913
Hydrology (Soil Moisture)	Estimation of Stress in Spring Wheat Using Landsat Data	J. Price V. Salomonson	913
Ice Survey	Ice Survey Using Nimbus Microwave Imagery	A. Chang	913
Land Use	Taiwan Land Use Survey	A. Chang	913
Landsat Data Analysis	Virginia Landsat Scene Analysis	C. Schnetzler	923

Applications Discipline	Investigation Title	GSFC Investigator	GSFC Branch Code
Bathymetry	Bathymetry Study Using CZCS Aircraft Data	J. Barker B. Middleton	923
Coastal Mapping	Radar/Landsat Coastal Mapping Study	H. Moller	Wallops
Hydrology	Snowmapping Study	A. Rango J. Foster	913
Land Use	Lake City, Florida Land Cover Survey	C. Schnetzler	923
Agriculture	Central China Irrigation Survey	L. Shima	923
Geology/Environment	Environmental Inventory - Central Maryland	A. Anderson	923
Ice Survey	North Pole Ice Survey - Nimbus Data	J. Zwally	911
Hydrology	Anacostia Watershed Study	R. Ragan	913
Geology	Geological Mapping of Wind and Powder River Basins	N. Short	923
Land Use	Richmond, Virginia Land Use Survey	B. Sellman	923
Forestry	Washington, D. C. Tree Health - Disease Stress Survey	W. Sopstyle	Wallops
Radar Data Analysis	Joint Radar/Landsat Data Analysis Study	H. Moller	Wallops